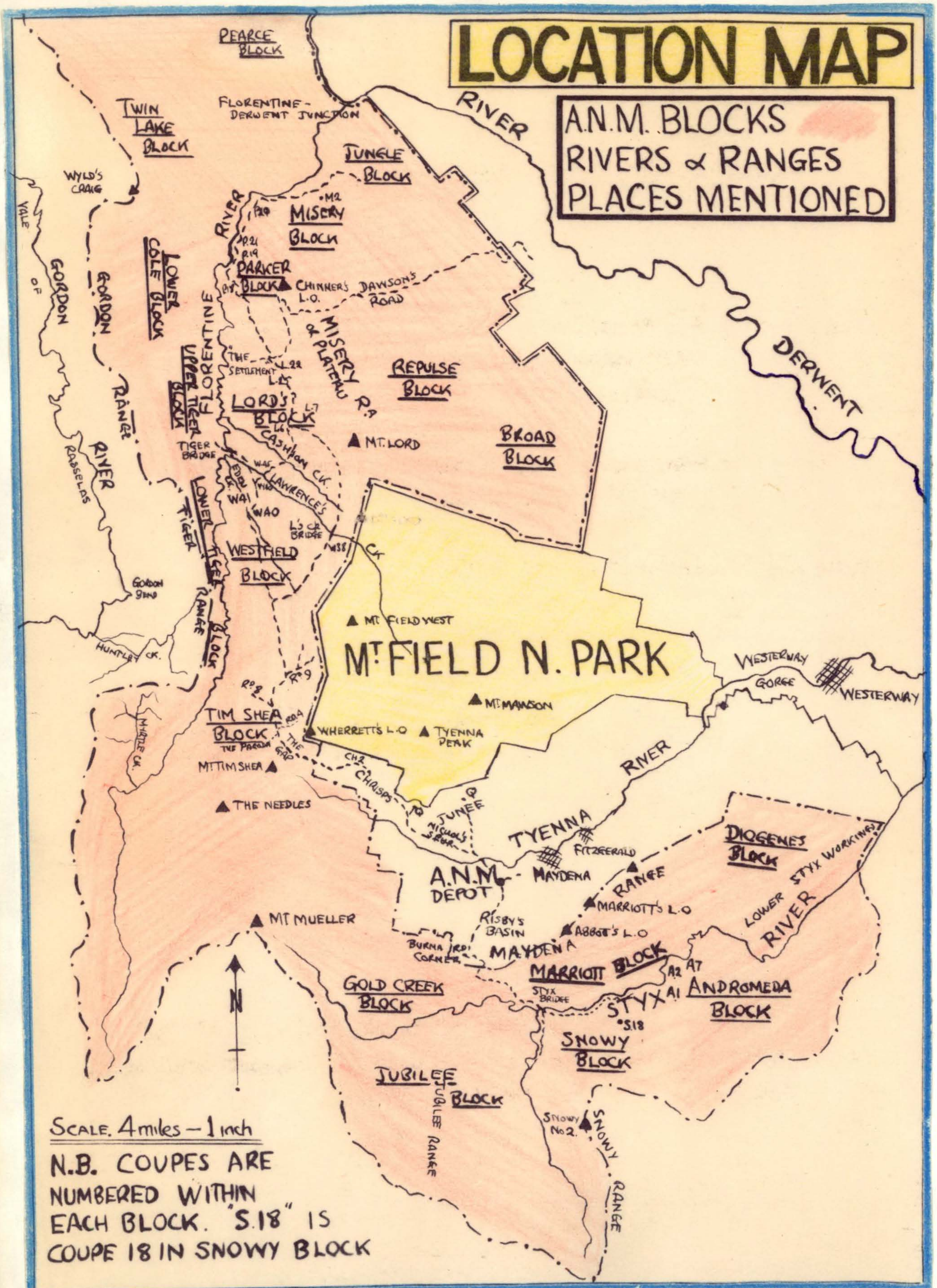
STUDY AREAS

NT 130


LOCATION MAP
A.N.M. BLOCKS
RIVERS & RANGES
PLACES MENTIONED
PEARCE BLOCK
TWIN LAKE BLOCK
FLORENTINE-DERWENT JUNCTION
RIVER
DERWENT
JUNGLE BLOCK
WYLD'S CRAIG
VALE OF GORDON
MISERY BLOCK
FLORENTINE RIVER
LOWER COLE BLOCK
PARKER BLOCK
CHINNER'S L.O.
DAWSON'S ROAD
GORDON RIVER
GORDON RANGE
MISERY PLATEAU
UPPER TIGER BLOCK
THE SETTLEMENT
REPULSE BLOCK
LORD'S? BLOCK
CASHION CK.
MT. LORD
BROAD BLOCK
TIGER BRIDGE
RASSELAS
LAWRENCE'S CK
LOWER TIGER BLOCK
TIGER RANGE
WESTFIELD BLOCK
GORDON BEND
MT. FIELD WEST
MT. FIELD N. PARK
HUNTLEY CK.
TIM SHEA BLOCK
THE GAP
MT. MAWSON
WHERRETT'S L.O.
TYENNA PEAK
WESTERWAY GORGE
WESTERWAY
MYRTLE CK.
MT. TIM SHEA
CHRISPS
THE NEEDLES
JUNEE
NICHOLS SPUR
TYENNA RIVER
TYENNA
FITZGERALD
MAYDENA
DIOGENES BLOCK
LOWER STYX WORKINGS
A.N.M. DEPOT
RANGE
MARRIOTT'S L.O.
MT. MUELLER
RISBY'S BASIN
ABBOTT'S L.O.
BURNA RD. CORNER
MAYDENA RANGE
MARRIOTT BLOCK
STYX RIVER
GOLD CREEK BLOCK
STYX BRIDGE
ANDROMEDA BLOCK
S.18
SNOWY BLOCK
N
JUBILEE BLOCK
JUBILEE RANGE
SNOWY No.2.
SNOWY RANGE
SCALE. 4 miles – 1 inch
N.B. COUPES ARE NUMBERED WITHIN EACH BLOCK. "S.18" IS COUPE 18 IN SNOWY BLOCK

THREE STUDIES IN FOREST ECOLOGY.

Part I A Survey of the Forests of the Florentine, Styx and Tyenna Valleys in Southern Tasmania.

Part II A Summary of Experimental Findings January 1957 to June 1961.

Part III Regeneration Surveys.

by

A. B. Mount. B.Sc. (Adelaide),
Dip.For. (Canberra).

This thesis is submitted in fulfillment of the requirements for the degree of Master of Science University of Tasmania, Hobart, September, 1964.

Declaration:

I hereby declare that, except where specifically indicated to the contary, this thesis is my own work and it is not substantially the same as any thesis which has already been submitted at any other University.

A.B. Mount.

Acknowledgements:

The work reported in this thesis was carried out at the Maydena Research Station of the Tasmanian Forestry Commission. The areas described are for the most part within the Australian Newsprint Mills Concession. The management and members of this company were at all times most co-operative and helpful.

This thesis was prepared under the supervision of Dr.W. Jackson of the University of Tasmania whom I wish to thank for his constructive criticism and encouragement.

Special thanks are due to Dr. J.M. Gilbert whose thesis forms the ecological foundation upon which I have attempted to build, and to Dr. T.M. Cunningham for his continual guidance in work at Maydena and for his great help in the matter of regeneration survey techniques.

Perhaps most help came from Mr. K.W. Cremer with whom every new idea was argued out and whose researches provided such a stimulus to my own.

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PART III (cont.)

PART III C A NEW HETEROGENEITY FACTOR

List of Plates

Illustrations (Not including photographs)

Part I

Opposite Page No.

Part II

Part III

Illustrations (cont)

Opposite Page No.

Part III

Graphs (cont)

SUMMARY

The first part of this thesis is based on observations made in the forest and a discussion of the place of fire in the ecology. It is concluded that there has been ecological equilibrium for several thousand years except in areas where man's pattern of behaviour has recently changed. It is argued that this equilibrium is dynamic and that it takes the form of "fire-cycles".

The second part deals with some experiments carried out during the period 1957-61.

The third part discusses regeneration surveys in Tasmania and in other parts of the world and then proposes a new factor of heterogeneity "h" which appears to have several advantages over existing factors.

<u>N.B.</u> More detailed summaries are included at the ends of each section, namely on pages 36, 51 & 52, 82-85, 95A, 112, 122 and 140.

Table 2 TEMPERATURES AT MAYDENA

Temperatures (^{o}F) per month at Maydena Meteorological Station between 1952 and 1960. (Screen Maxima and Minima)

	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.	Year.
Mean Daily	59	58	54	50	46	42	41	42	46	48	52	56	--
Mean Max.	72	69	66	59	53	49	49	50	56	58	62	66	--
Mean Min.	47	47	44	42	39	36	33	35	36	37	42	45	--
Extreme Max.	103	89	89	81	68	67	75	65	72	82	86	96	103
Year	'59	'59	'60	'58	'52	'56	'56	'54	'54	'57	'53	'60	1959
Extreme Min.	30	31	30	21	26	20	20	20	23	20	30	28	20
Year	'54	'55, '60	'54	'58	'59	'56	'56	'60	'55	'58	'55	'52	'56, '58 '60

Table 3 A COMPARISON OF 1933/34 & 1960/61 SUMMER RAINFALLS

FITZGERALD

	A.	S.	O.	N.	D.	J.	F.	M.	A.	August to April Total	Av.	%of Av.
1933/34	345	364	510	180	48	99	120	225	343	2234	3596	62%
Extremes	227	175	150	176	48	88	96	126	119	1205		33½%
Differences	118	189	360	4	0	11	24	99	224	1029		28½%

MAYDENA

	A.	S.	O.	N.	D.	J.	F.	M.	A.	Total	Av.	%of Av.
1960/61	143	375	492	402	39	148	127	113	258	2097	3442	61%
Extremes	143	123	246	218	39	89	127	106	103	1194		34%
Differences	0	252	246	184	0	59	0	7	155	903		27%

November to February 1933/34 - 447 points (Only 39 points above Summed Extremes)

December to March 1960/61 - 427 points (Only 66 points above Summed Extremes)

Hence 1960/61 was drier then 1933/34 but in 1933/34 the drought started one month earlier.

Table 4 PRECIPITATION AT "THE SETTLEMENT"

(11 miles north of Tim Shea)

5/57 - 4/62 Averages 5 years (approx 1200' A.S.L.)

J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.	Year 1958/61
151	227	245	480	678	385	361	419	359	482	327	399	45.91

Table 5 PRECIPITATION AT "TIM SHEA"

(8 miles west of Maydena)

1/1955 - 12/1961 inc. Averages 7 years (approx. 1600' A.S.L.)

J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.	Year.
278	213	274	553	682	531	510	570	416	561	520	474	55.89

Table 6 PRECIPITATION AT SOUTH STYX

(6 miles south of Maydena)

8/1957 - 4/1962 Averages 4 to 5 years (approx. 1500' A.S.L.)

J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.	Year.
206	278	287	503	733	500	472	480	450	534	367	419	52.29

From Table 1.

It is noteworthy that the occurrence of maximum monthly rainfalls is much more frequent in the early years, at least for Maydena.

Maydena	1945 - 1952 (8 years)	9 maxima, 3 minima.
	1953 - 1961 (9 years)	3 maxima, 9 minima.
Fitzgerald	1924 - 1938 (15 years)	9 maxima, 6 minima.
	1939 - 1954 (15 years)	3 maxima, 6 minima.

At Maydena Station 8 minima have occurred after 1954 suggesting that if the Fitzgerald records had been kept up they would also show the Maydena pattern.

Surrey Hills data for the 44 years from 1917 to 1961 inclusive, has a similar distribution pattern of monthly maxima as Fitzgerald, e.g. :-

22 years prior to 1/1939 - 10 maxima, 6 minima.

22 years since 1/1939 - 2 maxima, 6 minima.

The driest year was 1950 - 53.40 inches.

The wettest year was 1923 - 101.14 inches.

Averages - 1st 22 years 78.95". 2nd 22 years 73.73".

This relatively limited evidence suggests that the rainfall may be decreasing very slightly, at least since 1930. This could have been caused by changed micro-climates near the three rain gauges, or even due to movements of the gauge (e.g. Fitzgerald). It may be a true measure of climatic change. The fire pattern in the Florentine would suggest that there was a wet period from about 1840 to 1930 with another drier period before 1840. However, the fire pattern before 1840 may not reflect a drier climate but a stage in the ecological cycle (see later). The longest kept records of climatic effects for Tasmania are those of rainfall. Unfortunately, the further back the records go the fewer and more unreliable they become. There does, however, appear to be evidence of some fluctuation in rainfall, at least in N.W. Tasmania.

Needham (1960) showed that the average annual rainfall for Waratah increased 10" in the last 75 years. If the data for this station is re-examined it will be found that there was a sharp jump in average rainfall in 1903 and since then it has been remarkably constant, e.g. (Years in brackets).

Av. 1883-1902 1. excl. 1895, 1896 (incomplete records) -
78.91" (18)

2. inc. estimates for 1895, 96 approx.
79.8" (20)

Average 1903-1922 91.8" (20)

Average 1923-1942	88.3 (20)
Average 1942-1961	88.9 (19)
Average 1903-1961	89.7 (59 years)

This remarkable jump is substantiated by records for Zeehan, Burnie and Stanley. However, rainfall 1872 was an all time record for Stanley and there appears to have been a wet period over most of the State about this time (i.e. before 1882).

In all, it is concluded that long drier periods may occur but that the change does not appear to be permanent. It is even possible that the sudden change at these four stations in 1902 to 1903 may be due entirely to better siting of the gauges in that year. Or even, as was later proved for Longford, to a change in cylinder size for the same gauge size.

Most long term trends appear to be towards a decreased rainfall. Even this measured decrease in rainfall is far more likely to be a true record of the change actually occurring in, but limited to, the immediate vicinity of the meteorological stations, than to be a true record of the climate as a whole. Almost invariably these meteorological stations are in valley bottoms, often in cities, while the forests are generally removed, horizontally and vertically.

Rainfall at Maydena is seldom intense compared with that in tropical areas or even with storms in the drier parts of Tasmania. The record for one day being 303 points in April 1960. On the same day much of Southern Tasmania and Eastern Tasmania received from 6" to 12" (Hobart and Derwent Valley floods 1960).

Precipitation tends to decrease towards the Northern end of the Florentine Valley, see Table 4 - The Settlement, and to the Eastern ends of the Tyenna and Styx Valleys. Moreover these latter two areas come less under the influence of the South Westerly winds and are more affected by South Easterly rain patterns. Precipitation increases between 4" and 8" per 1000' altitude, see Tables 4 and 5 and data for Lake Fenton - 3450' ASL. 6340 pts(from Gilbert 1959).

Snow can be seen on the Southern slopes of Mount Field West in any month of some years (1957) and it falls onto the Valley floors on several days of every year. It seldom lies on the ground for more than a few hours at the lower altitudes although in 1946 logging in Risby's Basin (1100', Tyenna Valley) was held up by snow for 10 or more days. The chief nuisance of snow is in closing "the Gap" (2000') to vehicular traffic on two to three days each year. On such days snow is generally also found lying on the floor of the Florentine Valley (1200 - 1400'). Snow damage occurs but it is probably most important where small Eucalypt seedlings are growing under ferns.

Other sources of precipitation are the frequent valley fogs in the winter and dew in the summer.

One further rainfall pattern of interest is that dry years are typified by a high proportion of months having less than average rainfall, whereas wet years are caused by exceptional rainfall occurring in only one, two or three months of the year. All months between November 1949 and February 1951 were below average and resulted in the record low rainfall of the year 1950 (2903 points). 1954 (3952 points) had 9 months below average, 1959 (3988 points) had 9 months below average, 1960 (3955) had 10 months below average. In 1946 (6247 points) only 6 months were above average but record rains fell in February, July and August. In 1947 (6242 points) only 5 months were above average but record rainfall in June. In 1958 (6317 points) only 5 months were above average but 1816 points fell in May.

Frost

Frost damage is most severe on small seedlings on disturbed soils. Before the advent of the tractor it was probably not very important. No frost hollows have been seen in the valley. Frost is probably most important in helping to preserve the plains found at higher altitudes and in the Gordon Valley.

Wind

Cremer (1961) reports that for the Tyenna Valley 80% of all winds come from westerly directions but that the orientation of the valley caused this 80% to be equally divided between N.W. and S.W. This effect would possibly be less marked in the upper part of the Styx Valley, but even more marked for the part East of Gold Creek and Jubilee blocks. The N-S orientation of the Florentine Valley tends to channel N.W. winds into Northerlies and S.W. winds into Southerlies (in Tim Shea block). Further up slopes of the Field West, Misery Range, the westerly winds probably blow unimpeded by the Tiger Range at least for Tim Shea, Westfield and Lords blocks.

The gap between Mt. Tim Shea and the Southern end of the Tiger Range probably accounts for the higher rainfall in Tim Shea and part of Westfield blocks. Most of the rest of the valley floor is in the rain shadow of the Tiger and Gordon Ranges.

Wind storms are very rare - as would be expected in an area where most trees are able to grow over 200 ft. tall. There is so little wind at the top of Mt. Tim Shea that the windmill generator for the radio relay station there had to be augmented with a motor. Cases of extensive wind-throw have been seen only on the N. aspects of the Snowy Range and in an E. obliqua Phyllocladus stand on very wet soils. However, the broken tops of many overmature eucalypts can be attributed to the combined effects of wind and fire or wind and fungal damage.

Rain can come with winds from almost any direction. Dangerous fire winds come from the Northern half of the compass.

With so tall a forest and its dense understorey, wind near the forest floor is negligible even while the strongest winds are blowing in the tree tops. The wind speed drops especially sharply at the level of the rainforest canopy, even when the rainforest understorey has just been killed by fire. The same reduction occurs with dense wet sclerophyll understorey but this is generally closer to the ground.

Lightning

Lightning fires occurred in this area as follows :- (1950-62)
1950 - Depot, 1956 - Rd. 8, 1955 (?) W.10, 1961 - Marriott block.
1962 - Andromeda and Tyenna Valley.

and evidence of an old strike at the back of Rd. 8 was seen in 1958.

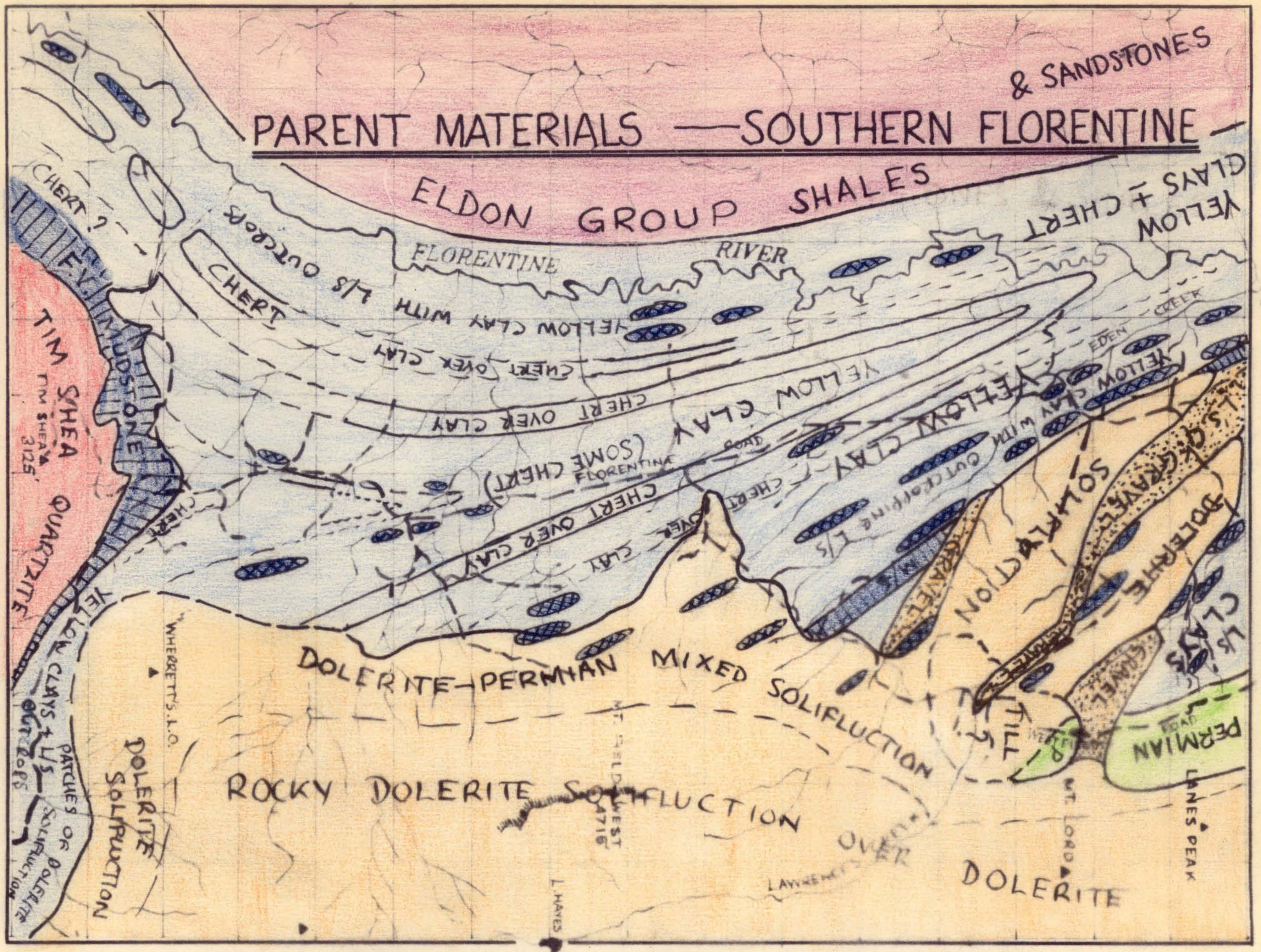
Although electrical storms are relatively rare here and dry electrical storms even rarer, the presence of so many tall trees with dry dead wood in their crowns offers a very good chance of lightning causing fire.

Topography

All forested areas discussed lie above 900' ASL. Economic forest occurs ~~above~~, to a limited extent ~~only~~, above 3000'.

The Florentine forests lie between Mt. Tim Shea and the Derwent-Florentine Junction. The Southern three quarters of this area forms a broad, nearly flat, valley 1100 to 1600' above sea level. It is bounded to the West by the Tiger and Gordon Ranges which rise from 2000' in the South to 4388' at Wylds Craig to the North. To the East, the valley is bounded by the Misery Plateau rising from 2000' in the North to join the Mt. Field block (4700') and then falling again to Wherretts L.O. (3500') in the South.

The major gap in the mountain wall surrounding the valley is that between Mt. Tim Shea and the Southern end of the Tiger Range. A narrower gap occurs to the North where the Florentine drops steeply into the Derwent. The Tyenna Gap at 2000' and the Lawrences' Creek Valley are the only breaks in the Eastern wall. A few creeks from the North tend to produce a rather more irregular Northern boundary but do not prevent the highland there from forming an important natural barrier. With the biggest gap to the Southwest where the wettest weather comes from, this 90% complete wall of mountains rising from 600' to 3000' above the valley floor probably gives it good protection from winds. However, any Northerly winds can still blow with considerable effect especially in the broader part of the floor. The mountains


PARENT MATERIALS — SOUTHERN FLORENTINE
& SANDSTONES
ELDON GROUP SHALES
YELLOW CLAYS + CHERT
FLORENTINE
RIVER
CHERT ?
CHERT
YELLOW CLAY WITH L/S OUTCROPS
CHERT OVER CLAY
CHERT OVER CLAY
YELLOW CLAY
YELLOW CLAY
(SOME CHERT)
FLORENTINE
ROAD
CHERT OVER CLAY
CLAY
YELLOW CLAY WITH OUTCROPPING L/S
EDEN
CREEK
YELLOW
TIM SHEA QUARTZITE
TIM SHEA 3125
MUDSTONE
YELLOW CLAYS + L/S OUTCROPS
PATCHES OF DOLERITE SOLIFLUCTION
DOLERITE SOLIFLUCTION
SOLIFLUCTION
GRAVEL
L/S & GRAVEL
DOLERITE
L/S CLAYS
TILL
PERMIAN
ROAD
DOLERITE-PERMIAN MIXED SOLIFLUCTION
ROCKY DOLERITE SOLIFLUCTION
OVER
DOLERITE
WHERRETT'S L.O.
MT. FIELD WEST 4716'
L. HAYES
MT. LORD
LANES PEAK

may also have an important effect on the rainfall, accounting for much of the difference of 10" between Tim Shea and Settlement rain gauges. The Tim Shea gauge is exposed to the Westerlies, the Settlement gauge is in the rain shadow of the Tiger and Gordon Ranges.

The Styx and Tyenna Valleys are somewhat alike in shape as both are bounded by ranges to the N.W. and S.E. which tend to imprison the rivers towards the East. Both open out into broad basins in their upper reaches, and the Tyenna Valley has a quite extensive flat floor to the West similar to the upper Florentine.

At Maydena the floor of the Tyenna Valley is just above 800'. At the Styx Bridge the river runs at about 1200'.

The containing ranges are : the Mt. Field Block - with Tyenna Peak and Mt. Mawson (both above 4000') the principal heights; the Maydena Range, which reaches nearly 3600' at Marriotts and Abbotts' Look-outs but which falls away to East and West; and the Snowy and Jubilee Ranges forming the Southern boundaries. Mt. Mueller (3,900') lies at the Western end of the Tyenna Valley but the low saddle to the South leaves both this and the Styx Valley less well protected than the Florentine except from the North and South.

Geology and Soils

Gilbert (1958) described the geology and soils of the Florentine in his thesis. However, observations in the Coupe register give a better appreciation of the extent of the various soils and have enabled the construction of a soils map for most of the Florentine and much of the Styx Valley and Tyenna Valley.

(a) The Florentine Valley

1. Limestone Soils The Gordon Limestone underlies most soils on Tim Shea, Westfield, Lords and Lower Tiger blocks and at least half of Parker, Lower Cole and Upper Tiger blocks. The

PLATE 3 THE YELLOW CLAY DERIVED FROM THE GORDON LIMESTONE

Limestone rock Sample (a)	Clay next to rock Sample (b)	Clay 3' from rock Sample (c)

Although not obvious in this picture, the bedding planes of the Gordon Limestone can be found extending from the solid rock through into the clay for several yards. These lines are often in the form of thin fragments of impure limestone. The indications are that there has been weathering of the rock in the situ without collapse, the voids in the weathered product being filled with water.

The great increase in Aluminum following weathering probably indicates the formation of clay minerals which would help to explain this lack of collapse of what at first sight appears to be fairly pure limestone.

surprising feature is the extent to which these soils bear little, or no, resemblance to the underlying rock.

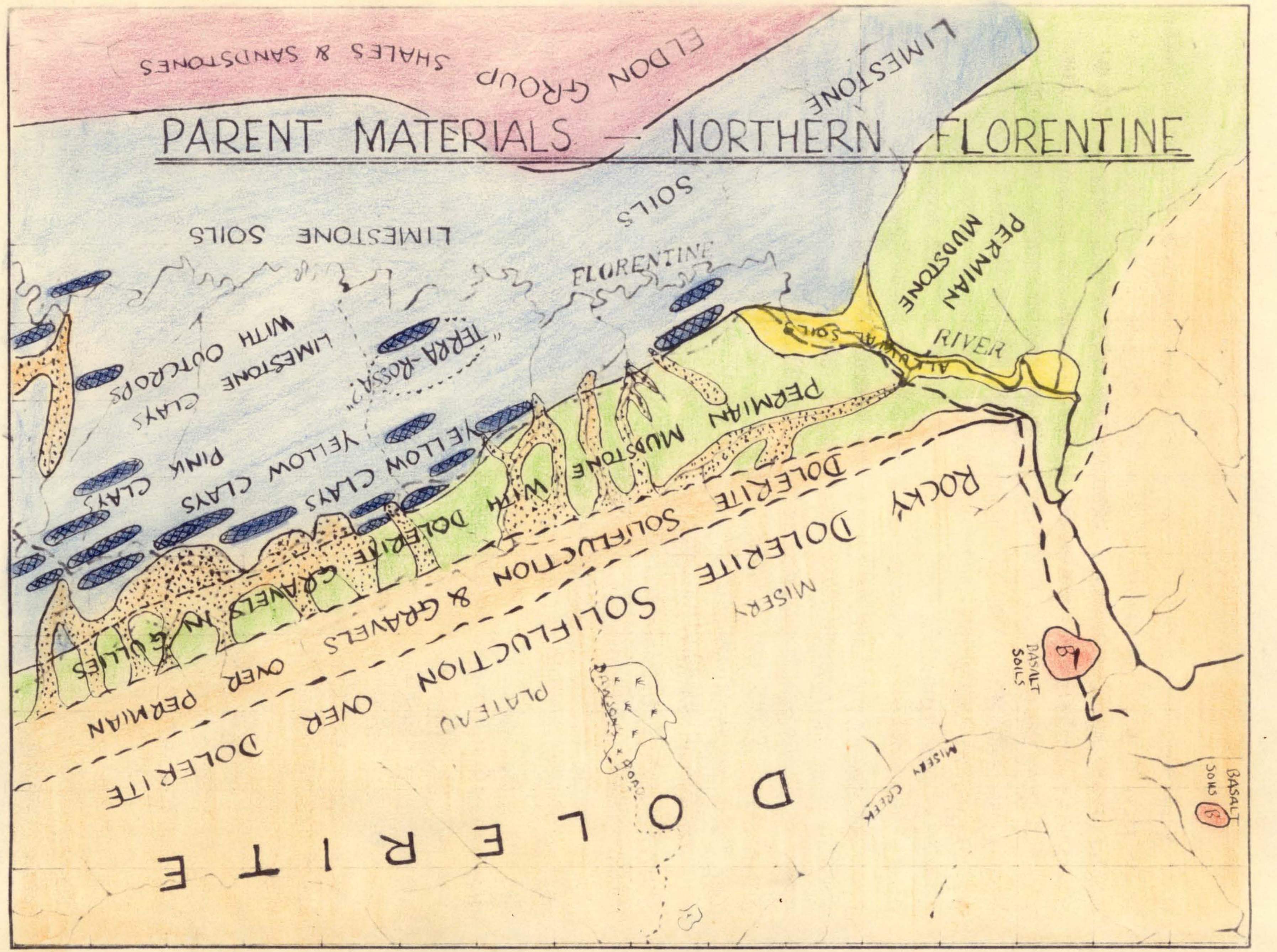
There has been intensive silicification of the limestones in the area between Mt. Tim Shea, Eden Creek and the Tiger Range, with limestone outcrops fairly rare in this area. The soils are either deep yellow clays (pH 5.3-5.7) often containing nodules of pyrite or iron concretions, or humus soils on white chert gravels (pH 4.1-4.4) or a mixture of both (pH values by Nicholls from Gilbert's thesis).

M. Banks (1961) of the Geology Department considers that the chert developed by replacement of limestone by silica soon after the deposition of the rock. He also considers that the yellow clays, seen best at Rd. 9 junction, are products of decomposed impure limestone (as opposed to chert - silicified limestone).

To test the latter hypothesis, three samples were taken from this area and sent to the Government Analyst. The samples were chosen from an area where the bedding planes of the decomposed limestone can be seen continuing into the yellow clay. The three samples were - (a) the undecomposed rock; (b) the adjacent clay, and (c) the clay 3' away, all in the one bedding plane.

The results of the analysis are summarised as follows -

		(a)	(b)	(c)
1.	Density as received	2.70	1.59	1.64
2.	Density after drying 105°C.	2.70	1.21	1.18
3.	pH (paste)	-	8.0	4.8
4.	Mineral analysis (expressed as g/100ml. of original sample)			
	Loss on ignition	73.5	5.0	5.7
	(CO_2)	70.6	0.48	0.01
	Acid insoluble (Mostly SiO_2)	94.1	88.0	94.6
	Iron (Fe_2O_3)	5.1	5.5	6.2
	Aluminium (Al_2O_3)	0.1	2.0	1.8
	Calcium (CaO)	90.6	0.5	0.2
	Magnesium (MgO)	8.9	1.5	0.7
	Moisture		55.4	52.8
	TOTALS	272.2	157.9	162.0

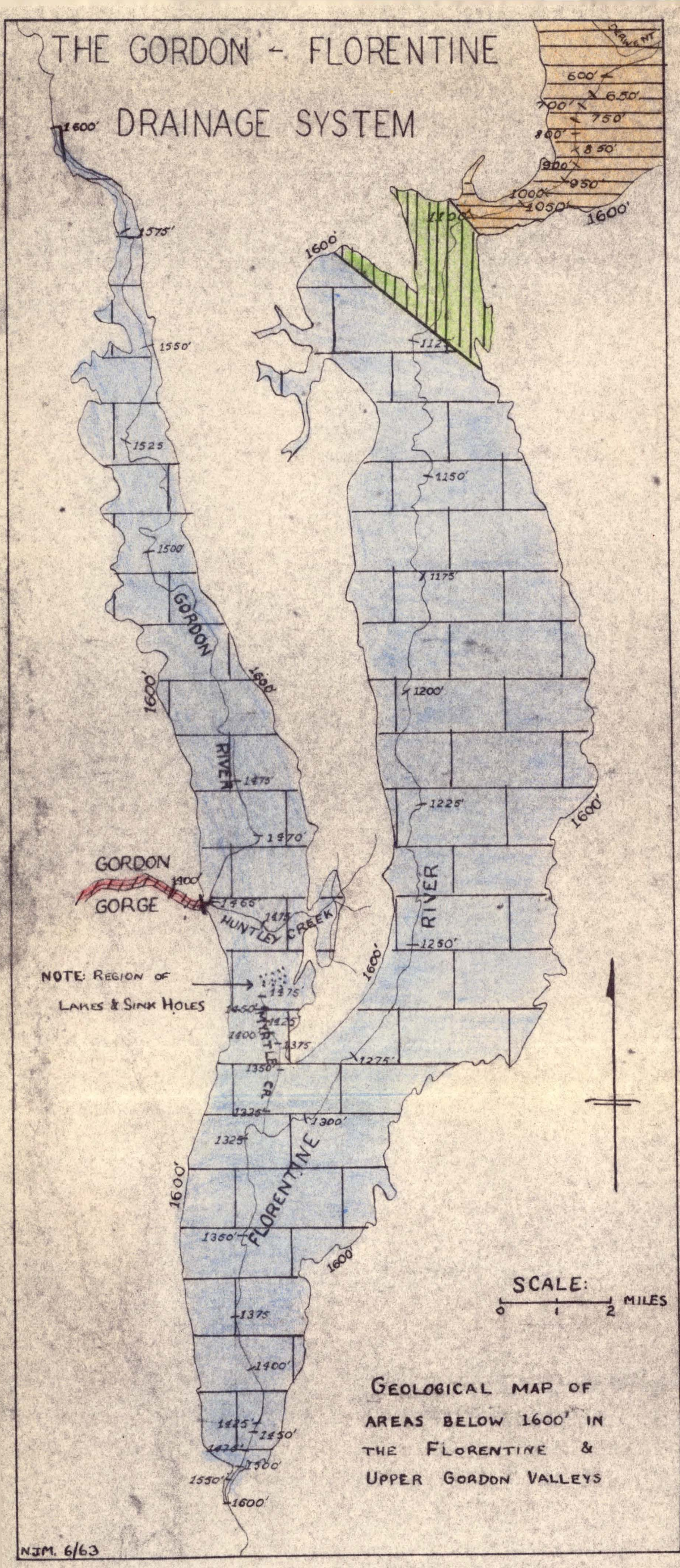

PARENT MATERIALS — NORTHERN FLORENTINE
ELDON GROUP
SHALES & SANDSTONES
LIMESTONE
LIMESTONE SOILS
SOILS
FLORENTINE
LIMESTONE WITH OUTCROPS
CLAYS
"TERRA-ROSSA?"
YELLOW CLAYS
PINK CLAYS
YELLOW CLAYS
PERMIAN MUDSTONE
ALLUVIAL SOILS
RIVER
PERMIAN MUDSTONE WITH DOLERITE
GRAVELS IN GULLIES
DOLERITE SOLIFLUCTION
SOLIFLUCTION & GRAVELS OVER PERMIAN
ROCKY DOLERITE
SOLIFLUCTION OVER DOLERITE
MISERY
PLATEAU
DOLERITE
BASALT SOILS
MISERY CREEK
BASALT SOILS

From this analysis it appears almost certain that the clays have been formed by de-calcification of the limestone with some replacement by aluminium. The relatively small quantities of aluminium could have accumulated from weathered limestone above but if this is so what has happened to the enormous quantity of "acid insoluble"? These yellow clays lie unchanged from a few inches below the surface to depths in excess of 200' in places. (Borings for proposed tunnel at "The Gap"). It may be that the "acid insoluble" material has been slowly dissolved and carried away in the ground water while the aluminium has been retained in the form of stable clay minerals. However, the aluminium more likely came by ground water from the Dolerite to the East. Magnesium appears to be slightly less soluble than calcium and may be chiefly responsible for the high pH adjacent to the rock.

Black rendzina-like soils are found on all limestone outcrops in the Florentine and Dimmock (1962) has described a true Terra Rossa at Maydena quarry.

It is likely that the main difference between the conventional limestone soils and the yellow clays is due to drainage. On well drained sites the limestone also weathers chemically by de-calcification but the weathered products tend to get washed away. Neither soil, nor ground water, accumulates. Because of their better drainage, the chemical weathering of outcrops is perhaps less rapid than of other limestones. This would help to account for considerable outcrops near the Florentine River, Eden and Cashion's Creeks and along the East boundary of the deposit.

In Lord's Block at the N. half of Westfield Block, the clay becomes reddish and its depth suggests that it is the product of drainage intermediate to that of the yellow clay and a true terra rossa. This change in colour is more likely due to the oxidisation of the ferrous component in the clay to ferric due to an improvement in drainage after the deep clays were developed.



KEY:

	SLOPE OF RIVER VALLEY
DOLERITE	500' in 4 miles = 125' per mile
PERMIAN SEDIMENTS	25' in 2 miles = 12·5' per mile
QUARTZITE	Approx 70' per mile.
GORDON	A: FLORENTINE: 1125'-1375' – 250' IN 21mi. = 12' per mile. B: GORDON:

The chert gravels cap most ridges in Tim Shea and Westfield Blocks and form gravel flats near the "Resection Point" and in other flats in Westfield Block. These ridges are parallel to the bedding planes of the underlying limestones and were most likely derived from the chert bands in them.

The lack of chert to the North and East is due to the increasing purity of the limestone in these directions.

2. <u>The Florentine-Gordon Drainage System.</u>

Jennings (1955) suggested that the Florentine River once flowed South and then West and North to join the Gordon at "Gordon Bend". He points out that the extremely hard quartzite of the Gordon Gorge has acted as a bottle neck preventing rapid erosion of the limestone which forms the valley floor. Recent contour maps and other evidence are here used to fortify his hypothesis.

(i) <u>The slope of the valley floors</u>

Between the 1600' contour and the Gordon Gorge in the Gordon Valley there is a fall of 135' in 16 miles - <u>8' per mile</u>. In the Florentine Valley between the 1375' and 1125' contours there is a slightly greater fall - <u>12' per mile</u>.

Upstream of the 1300' contour the Florentine is joined by a tributary flowing down the western side of the Tiger Range. Up this tributary (Myrtle Creek) between 1325' and 1350' the slope of the valley increases to <u>30' per mile</u>.

From 1350' to 1375' it is <u>50' per mile</u>
From 1375' to 1475' it is <u>100' per mile</u>

As both valley floors are made of the same material the only explanation for the steeper parts of the grade is active erosion. The form that this erosion is taking is demonstrated by the region of lakes and sink holes immediately North of the head of Myrtle Creek.

<u>The heavy clays of the old floor of the Gordon Valley are being drained by a tributary of the Florentine and are collapsing</u>.

Extrapolating forward in time it is likely that, within a very short period of (geological) time, this tributary will capture the headwaters of the Huntley River and then the Gordon itself at Gordon Bend.

Extrapolating backwards in time it is likely that this river capture started close to the Florentine-Derwent Junction.

This means that the Florentine Valley must have, at one time, had similar heavy limestone clay soils at altitudes compatable with a slope of 10' per mile between them and the Gordon Gorge.

(ii) <u>The presence of heavy limestone soil in the Florentine Valley</u>

Heavy limestone clays can be found at 1700' in the Florentine Valley 13 miles from the Gordon Gorge. If it is assumed that the Gorge was then at a maximum of 1500' the fall is quite adequate (15' per mile). These clays are now 500' above the valley floor near the Limestone-mudstone boundary.

The only reasonable explanation for heavy clays of limestone origin and pale colour is that they were produced in conditions in which the only erosion was by solution, i.e., waterlogged conditions. But these conditions no longer apply in the Florentine Valley where these soils occur. Therefore the valley has been

PLATE 4 DOLERITE SOILS ON THE MISERY RANGE

(a) Completely rotted massive dolerite. Note pencil stuck in the middle of "boulder".

(b) Dolerite Solifluction over Rocky Dolerite. Note rocks on the surface, clay with small stones and massive rocky dolerite in that order down the profile.

(c) Till or Solifluction over Permian Mudstone. This layer of debris tapers from about 20' thick near Lawrence's Creek to nothing about 200 yards away.

drained after the formation of the soil. (Well drained conditions produce Rendzinas or terra rossas).

The two stages, WATERLOGGING followed by DRAINAGE cannot reasonably have been accomplished by the same river. Therefore, there was previously another outlet to the Florentine. The only other outlet is the Gordon Gorge.

The supreme anomoly of the two valleys is their difference in forest cover on identical geological formations. This is again explained by the succession of waterlogging followed by drainage. Drainage alone would have produced only relatively low quality forest. Waterlogging was required to produce the soils capable of supporting first-quality forest once they were drained.

3. Dolerite Soils

On top of Misery Plateau and for almost all blocks North of Twin Lake and Parker Blocks the soils are formed from a rotten dolerite clay overlain by sound dolerite boulders. Massive sound dolerite occurs in this clay but in no definite pattern. As with the limestone outcrops of the valley these sound dolerite outcrops are often associated with good drainage. Shallow depressions or gullies in the surface are able to hold great quantities of water without producing creeks, this causes areas of marsh which appear quite incongruous in so rocky a country. The dolerites range in thickness from about 600' in the North to at least 1500' at Mt. Field West (Jennings 1955).

In Lawrence's Creek Valley three different types of dolerite deposits are found. The first two deposits are seen best at Lawrence's Creek bridge. Here the boulders and clay are intimately mixed to a depth varying from at least 30' near the creek to a few inches at a distance from it. This is all called "solifluction debris" by Nicholls (Gilbert 1958) because it extends over the almost flat valley floor halfway to the Florentine River. However, some of it

PLATE 5 DOLERITE SOILS OF LAWRENCE'S CREEK VALLEY

(a) River Gravels under Till. Apparently the till choked the valley at the time of the last glaciation. This till flowed over the gently sloping floor of the Florentine Valley as a solifluction mantle. After the glaciation much of the till and the solifluction was washed down the valley, leaving two strips either side of the creek, and depositing the water sorted Lawrence's Creek gravels as the Creek subsided.

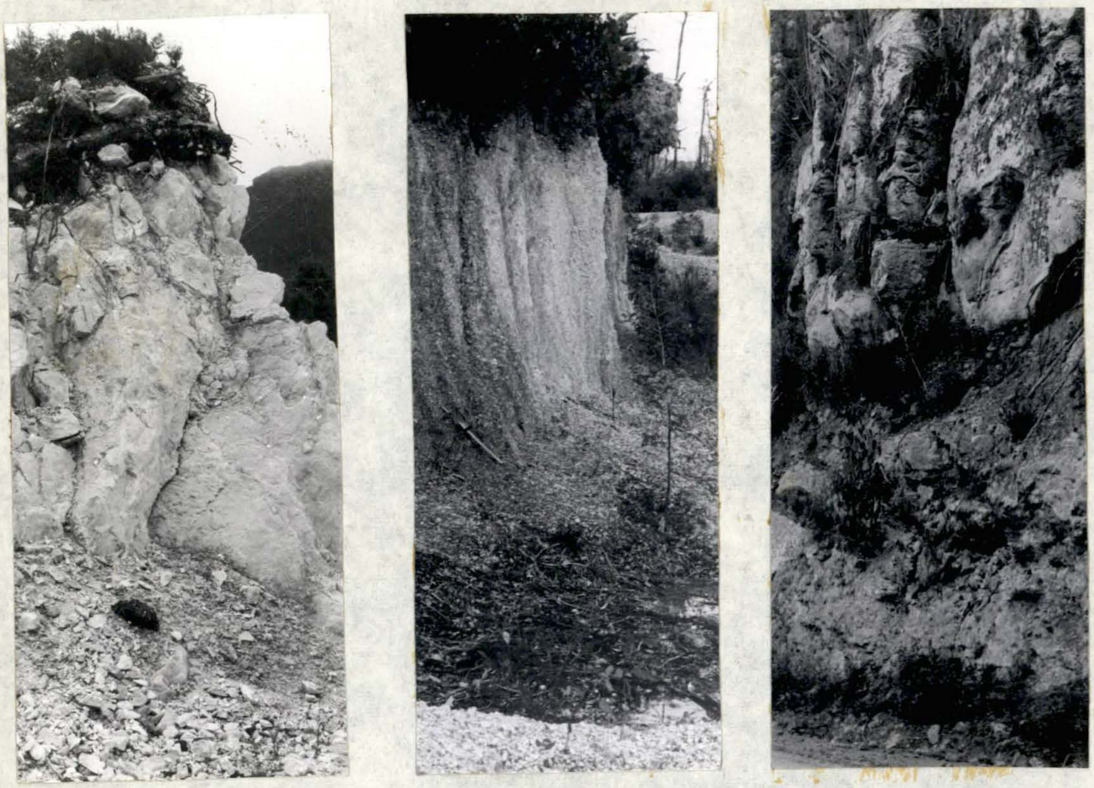
(b) Lawrence's Creek Gravels. Probably derived from the water sorting of the solifluction mantle.

to the East is probably glacial till. It appears to be a recent deposit originating about the time of the last glaciation (over12,000 years ago). Where it overlies the Permian mudstone a pale reddish-yellow clay is developed, where it overlies limestones a red clay is produced. The soil colour darkens and the texture lightens as the sheet becomes thinner to the North West.

Dolerite solifluction deposits occur below the whole length of the dolerite/Permian boundary, but they are probably less important and less thick here than Jennings has suggested (30 to 40'). They are commonly found as a sheet of a few feet thickness extending down a hundred feet or more below the boundary, and in association with creeks at lower altitudes. The soils they produce are generally dark red clay loams. No "rock rivers" or "boulder fields" occur in this area but true talus can be seen under the steep Western cliffs of Mt. Field West.

Dolerite materials also form the fluvio-glacial gravels which are found in the bed of Lawrence's Creek. Most appear to have been laid down shortly after the deposition of the "solifluction" material when the creek had considerably greater volume. Their deposition is probably associated with the end of the period of glaciation. These beds contain water only occasionally now when the underground channels in the limestone cannot take the volume. The soil found over these gravels is a red loam which represents the fine fraction deposited as the post glacial floods subsided. The gravels have hard smooth rocks showing no signs of weathering. It is likely that the rocks in the Lawrence's Creek gravels are/the ~~unrotted~~ core-stones of dolerite boulders that were otherwise well rotted in situ and then transported by glacial and periglacial action down the Lawrence's Creek Valley. Much of this heap of clay and rotten skinned boulders was then water sorted and chafed. Most of the

PLATE 6 QUARTZITE ROCKS AND SOILS



(a) (b) (c)

(a) Tim Shea Quartzites. Note black peaty soil.

(b) Chert from the Gordon Limestone. The soil is rather less peaty than in (a) because of a fairly high proportion of clay in the chert gravel. These chert ridges generally support harsher vegetations than the intervening limestone clays; e.g. dry sclerophyll, E.salicifolia, or Phyllocladus instead of wet sclerophyll, E.regnans or Atherosperma rain-forest.

(c) Massive Permian Quartzite. Not very important except as a guide to mapping the Permian sediments.

clay probably flowed all the way into the Derwent, the boulders were cleansed of their "shells" to form gravel stones and other shells provided most of the fines now found over the gravel.

At W.45, there exists an elevated terrace of gravels similar to those already described but apparently of greater age (assumed because they are elevated above the main gravel level). This may indicate two glaciations, probably fairly close together.

4. Soils over Permian Rocks

Between the Limestone and the Dolerite on the Eastern side of the valley are the almost horizontally bedded Permian sediments. These consist chiefly of mudstones, but have a narrow band of Greywacke (?) Conglomerates which makes mapping comparatively simple. The sediments have been subject to a series of faults which have tended to place the conglomerates band rather lower in the North (1200') than in the South (2000' near Lawrence's Creek). Similar deposits occur in the Styx Valley and on the Southern side of the Tyenna Valley.

The mudstone generally produces a yellowish-brown clay which resembles the heavy yellow clay of Gordon Limestone origin but is seldom so "sticky", nor does it exhibit "clay skins" when broken.

Mudstone solifluction soils in the Florentine occur to a limited extent only, over limestone clays in Lords Block.

The Greywacke Conglomerates often occur as steep rocky cliffs.

5. Quartzite Soils

The Tim Shea Conglomerates, the Caroline Creek Sandstone and the quartzites of the Jubilee Range all produce soils which are very acid, gravelly and infertile. The worst of the chert ridges in the Florentine produce the same sort of vegetation as massive quartzite. This vegetation is more sclerophyllous and more fire susceptible than that which occurs on most other soils.

6. Florentine Valley Mudstone

These Mudstones come between the Caroline Creek Sandstone and the Gordon Limestone and are exposed at the Tyenna Gap and on the lower slopes of Mt. Tim Shea. They produce a soil and vegetation similar to the Permian Mudstones, although the close proximity of quartzite from the Caroline Creek Sandstone may be responsible for the high proportion of E. obliqua sometimes found. Remnants of mudstone account for every patch of good Eucalypt timber and for all patches of good Nothofagus rainforest on the slopes of Mt. Tim Shea.

7. Other Deposits

Other Florentine deposits include :-

A small patch of shale near the Tiger Bridge but East of the Florentine. This is most likely part of the Gordon Limestone as it develops only a rather more rocky yellow clay.

Several marsh deposits occur near the course of the Florentine River which are probably caused by shallow depressions in the limestone being filled with chert gravels from further South. These deposits generally have black clay soils with chert gravel carrying a vegetation dominated by ti-tree.

Further "marsh deposits" (Jennings) on the Misery Plateau are a development of the shallow hollows in dolerite already discussed and both are probably high altitude solifluction mantles clogging the previous topographic variations (Davies 1962).

Basalt occurs in at least four places, at the Settlement and in Misery and Jungle Blocks. This rock develops the best looking soils in the whole area. The dark red clay loams are used extensively in nursery work.

The Tiger and Gordon Ranges are primarily shales and quartzites of the Eldon group with a dolerite capping reappearing near Wyld's Craig where it is estimated to be 1500' thick. Soils in these areas have not been sampled.

The Relationship between soils and Tree Height in the Florentine

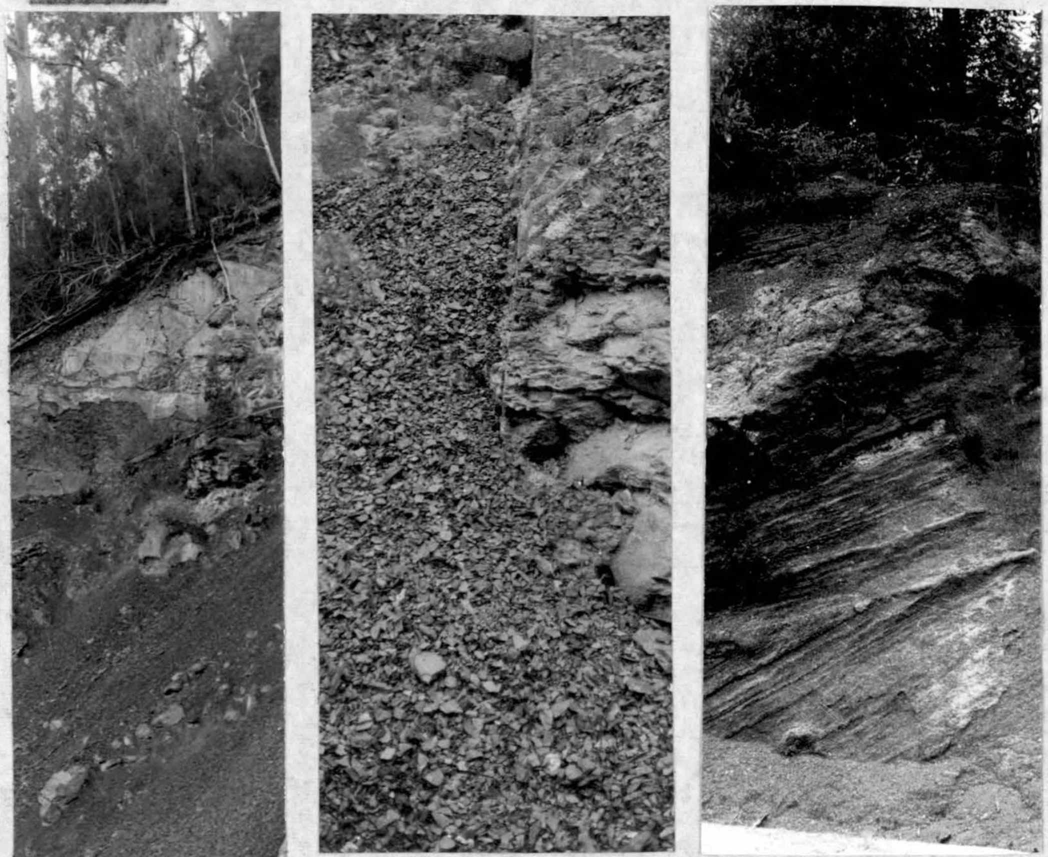
If tree height is taken as a measure of site quality the soils developed on the various deposits may be put into at least three classes, as follows:-

(a) Eucalypts below 180' In the Florentine the shorter stands of eucalypts occur where there is a high proportion of quartzite or chert in the deposit, at altitudes above 2400' on all soils, where drainage is extremely poor (gravelly flats) or extremely rapid (limestone outcrops).

(b) Eucalypts between 180' and 250' Most of the forests of the floor of the Florentine fall into this class and they occur on all soils not covered in (a).

(c) Eucalypts over 250' The tallest stands of E.regnans occur on alluvials of Permian origin (Parker); or on well drained deep clays of mudstone or dolerite origin. This good drainage is probably only found where these clays overlie limestone (Lords). Deep limestone clays over limestone may produce trees this tall but they have seldom been found. The presence of dolerite or mudstone clays or mixed clays over the limestone is attributed to solifluction processes.

PLATE 7 SOLIFLUCTION PAST AND PRESENT



(a) (b) (c)

(a) Permian Mudstone Quarry Note the heap of frost broken debris choking the bottom of the quarry. Note the protection that the vegetation gives to the mudstone at the edge of the quarry.

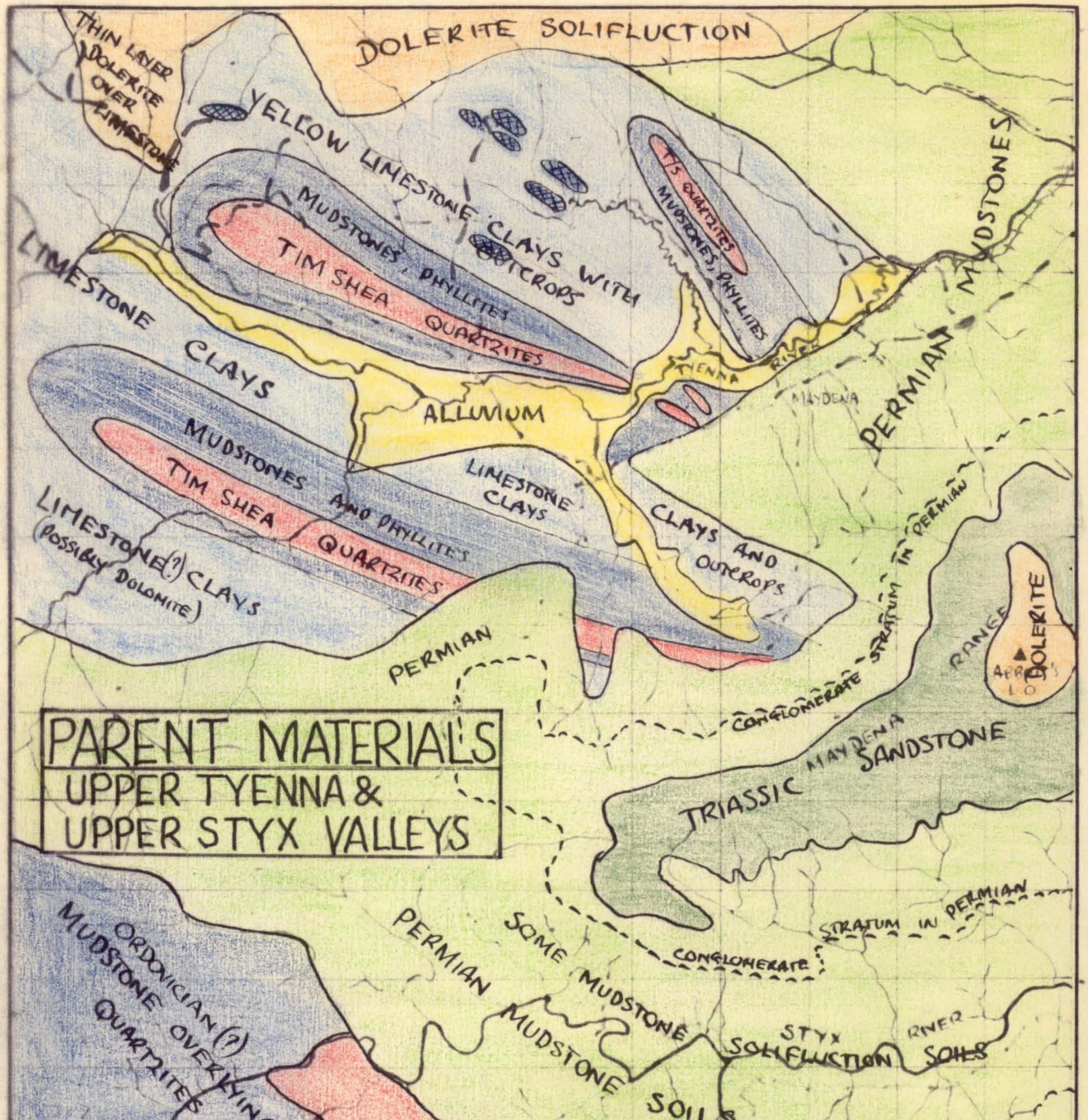
(b) Close-up of the Mudstone Debris Each frosty night these fragments on the surface are lifted perpendicularly to the surface on ice "stalks" up to 2" long. Each day these "stalks" melt and gravity takes their loads 2-3" down the slope. The supply of particles is maintained by frost broken particles from the quarry face. A quarry in similar rock near Taroona shows no heap of debris - probably because it experiences little frost.

(c) Peri-glacial Solifluction of Permian Mudstone

Geology and Soils

(b) Deposits of the Styx Valley The Geology of the Styx Valley is relatively uncomplicated. Practically all coupes logged so far are entirely on Permian sediment with mudstone predominating. A band of conglomerate similar to that found in the Florentine runs along both sides of the valley at least in Gold Creek, Snowy, Marriott, Andromeda and Diogenes blocks. The Jubilee Range extends into most of the Jubilee Block and consists chiefly of quartzites. Poor gravelly acid soils often carrying button grass extend along the ridges in the Block towards the Styx River, with most forest occurring in the gullies. Dolerite cappings occur on Abbott's and Marriott's lookouts on the Maydena Range and on Mt. Styx and most of the Snowy Range. Dolerite solifluction deposits descend onto the upper slopes of all blocks except Jubilee. Mudstone solifluction deposits extend right down to the Styx River in places. These deposits may be the most important in the whole valley as far as E. regnans occurs. Where mudstone is quarried and there is no solifluction mantle over the rock a much poorer quality of forest is sometimes developed, often dominated by E. obliqua.

Triassic sandstones occur in a small patch in Andromeda Block (A7, A1, A2) and as an extensive sheet near the top of the Maydena Range.


PARENT MATERIALS
UPPER TYENNA &
UPPER STYX VALLEYS
DOLERITE SOLIFLUCTION
THIN LAYER DOLERITE OVER LIMESTONE
YELLOW LIMESTONE CLAYS WITH OUTCROPS
MUDSTONES, PHYLLITES
TIM SHEA QUARTZITES
T/S QUARTZITES
MUDSTONES, PHYLLITES
TYENNA RIVER
MAYDENA
PERMIAN MUDSTONES
LIMESTONE CLAYS
ALLUVIUM
MUDSTONES AND PHYLLITES
TIM SHEA QUARTZITES
LIMESTONE CLAYS
CLAYS AND OUTCROPS
LIMESTONE(?) CLAYS
(POSSIBLY DOLOMITE)
PERMIAN
CONGLOMERATE STRATUM IN PERMIAN
DOLERITE
RANGE
TRIASSIC MAYDENA SANDSTONE
STRATUM IN PERMIAN
CONGLOMERATE
PERMIAN SOME MUDSTONE
MUDSTONE SOILS
STYX RIVER
SOLIFLUCTION SOILS
ORDOVICIAN(?)
MUDSTONE OVERLYING QUARTZITES
QUARTZITES
CONGLOMERATE STRATUM
QUARTZITES
SANDSTONES(?)
DOLERITE

Geology and Soils

(c) Deposits of the Tyenna Valley Relatively few coupes have been inspected in this area and the observations on soils etc. are limited. It seems, however, that many of the Florentine deposits occur on the North side of the valley, whilst most of the Styx ones occur to the South. (See also Map by Department of Mines 1953 - "Limestone Deposits in the Maydena Area").

Very deep deposits of Gordon Limestone occur under Tyenna Peak and are quarried at Dewhurst's and Junee Quarries. The same limestone extends from the Gap to East of Maydena. Limestones also occur in much of Risby's Basin, but except near creeks they are generally overlaid by dolerite solifluction material or mudstones.

Tim Shea Conglomerates and Caroline Creek Sandstones appear at least at Sunshine Spur and yellow clays and cherts are found under much short vegetation in the area between Sunshine, the Burma Road, Quarry and the Needles. These yellow clays and cherts are again probably derived from limestone or dolomite.

The conglomerate band of the Styx Valley is again found out-cropping at the Burma Road corner. Mudstones are found above and below this band.

Red-purple shales of the Junee Group (?) are found in Risby's Basin and under Sunshine Spur.

Dolerite solifluction deposits occur on both sides of the valley often associated with high level drainage systems. Examples of the deposits can be seen as low as 1200' in Risby's Basin and at about 1400' in Chrisps.

PLATE 8 VEGETATION TYPES

(a) Eucalypts over Wet Sclerophyll. E.regnans, E.viminalis and some Euc. gigantea over Pomaderris, Drimys, Pittosporum, Zieria, Coprosma, Ac.melanoxylon, Ac. dealbata and Olearia.

Soil is a red clay loam developed on dolerite solifluction materials with limestone about 10' below the surface.

This is the area of recent succession discussed in Part IC.

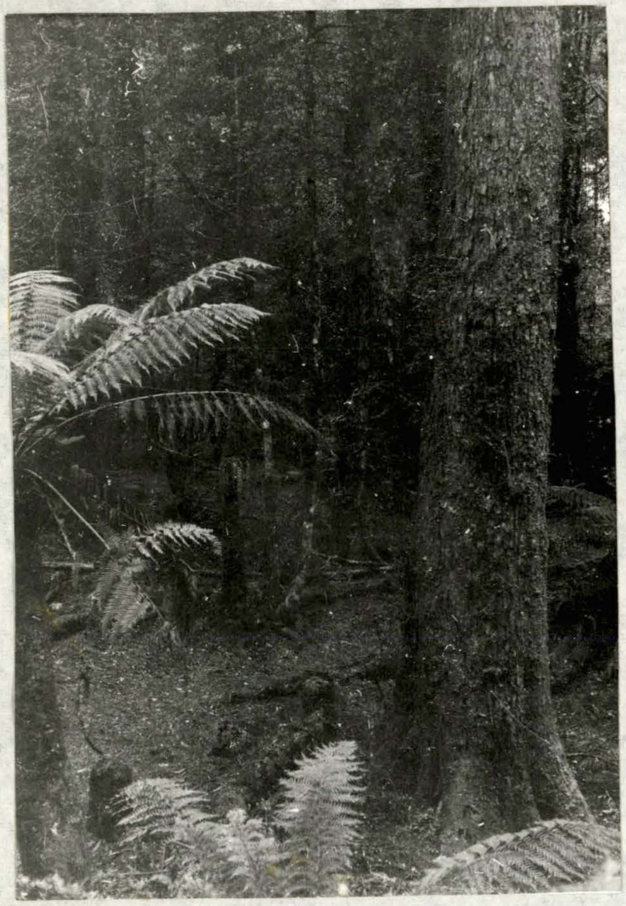
(b) Eucalypts over Mixed Rainforest and Wet Sclerophyll. E.gigantea and E. johnstonii over an intimate mixture of Nothofagus, Leptospermum, Ac.melanoxylon, Drimys, Phyllocladus, and Atherosperma.

Soil is "Rocky Dolerite" solifluction with clays under the surface rocks.

This mixture of the two major vegetation types is better marked at high altitudes but it occurs as a narrow ecotone along their common boundaries on the floor of the valley.

PLATE 9 VEGETATION TYPES (cont)

(a) Mixed Forest
E.regnans and E.obliqua over Nothofagus, Atherosperma, Phyllocladus and minor rainforest species.



(b) Pure Rainforest
Nothofagus cunninghamii, Atherosperma moschata, over Dicksonia antarctica, some mosses and little else.

NOTES ON VEGETATION TYPES AND THE MORE COMMON PLANT SPECIES.

The forests in the area are produced by the intermixing of the eucalypt with two major types of vegetation. They are the true temperate rainforest vegetation and the wet sclerophyll vegetation. Dry sclerophyll vegetation also occurs on some of the poorer sites.

Gilbert (1959) has clearly demonstrated that in this area the wet sclerophyll vegetation is ~~[illegible]~~ perpetuated by fire. This suggests that the various forest types could be classified by their fire frequencies, e.g.:-

1. Very frequent fires - only bracken, or Poa grass, are perpetuated.
2. Frequent fires - eucalypts with a low understorey of bracken or sclerophyll shrubs are found.
3. With a fire frequency of something like 20 to 40 years. Eucalypt forest with a tall wet sclerophyll understorey occurs. This will be called "Wet Sclerophyll Forest" in this thesis, although the term is used by Beadle and Costin (1952) to cover Section 4 and 5 also.
4. With a fire frequency of about 40 to 100 years, both vegetations can be well represented in the understorey under eucalypts.

5. With a fire frequency of about 100 to 400 years, Eucalypt forest with a rainforest understorey is found (Gilbert 1959 - "Mixed Forest").
6. Pure rainforest is found where the fire frequency is 200 to 600 years or more.

The eucalypts and species of the wet sclerophyll vegetation all germinate soon after a fire and are only very rarely able to regenerate under their own canopy. This produces stands in which ages are at least discontinuous, if not always, strictly uniform.

(a) Eucalypts

1. E. regnans This species is by far the most valuable for the production of groundwood pulp, it also produces a very valuable sawmilling timber. In the area studied so far, it is also the most abundant of the eucalypts. Mature trees are seldom less than 200' and often over 250' high. One tree in Snowy Block was measured by a registered surveyor and found to be 322' high. One stand in Andromeda Block, about 250-270 years old, has several trees over 300' and at least three about 320' high, but these have not so far been accurately measured. In the same stand, one veteran of 400 or more years, whose girth is 55', is still well over 300' high. This persistence of great height with great age is most unusual and may, in part, be due to a greater than usual ability to withstand wind. This resistance to wind damage is most likely due to an inherited resistance to decay in the heartwood of the upper stem. A genetic factor such as this is the most reasonable explanation for so tall a stand. Other factors possibly contributing to the great height of the 250 year stand are - optimum age (there are few stands of similar age in this area), a well drained mudstone ~~origin~~ clay next to sandstones; a site above the valley floor, but still protected from much of the

Plate 11 EUCALYPTUS REGNANS - ANDROMEDA

(a) General View of Reserve

The tree on the extreme left has been measured by theodolite and is 320'.

The tree on the extreme right is a 285' E.obliqua. The average height of the stand is over 300'

(b) The "Perfect Tree"

301' high, 30' girth, About 250 years old, 200' of clean straight stem.

(c) Closer view of the measured tree mentioned in (a).

This very tall stand is about 250 years old and 300' high. Choosing a tree to measure as the highest was impossible. The measured tree was chosen on the criterion of "greatest girth at greatest height". However it may be that the tallest trees are not those with the biggest stems. This was later found to be the case for the 285' E.obliqua.

(b)

(c)

Westerly winds by the Maydena Range, and the possibly beneficial effect of one or more light fires through the stand removing most of the understorey.

The greatest height and girth for a tree measured in the Tyenna Valley was recorded by Helms (1942) for one E. regnans at Nicholl's Spur (257' to broken top, 65' g.b.h. and 63,780 s.f.h. log volume). This tree is believed to have held the log volume record for E. regnans.

In the Florentine Valley, the tallest trees seen were just under 300' (Jungle Block, 160 yrs. and Westfield 350 yrs.) and the greatest girth 62' (Misery Block). However, no other valley in Tasmania, perhaps in Australia, carries such an enormous volume of timber as the Florentine. R.L. Newman's assessment figures (1957) show that the average pulpwood volume for Tim Shea, Westfield and Lords was over 65,000 s.f.h/ac with extensive areas carrying 100,000 to 110,000 s.f.h/ac common. Greater volumes per acre are recorded in Victoria (Cunningham 1960) but only in very small stands. Most of these great volumes occur in pure E. regnans stands.

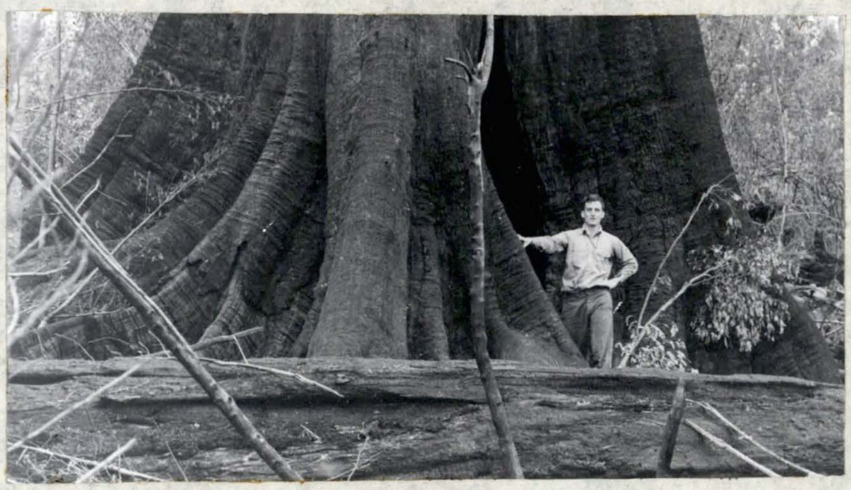
The greatest ages measured by ring counts are between 400-450 years. All of the three principal eucalypts in this area seemed to have similar longevities.

2. E. gigantea This is the second most valuable species for groundwood pulp and it produces a valuable sawmilling timber. It is probably equally abundant as E. regnans over the A.N.M. Concession area as a whole, but the extensive stands associated with higher altitudes and dolerite soils are only just beginning to be opened up. E. gigantea occasionally grows on the floor of the Florentine where it is often associated with shallow solifluction deposits, poorly drained cherty flats, or sometimes deep limestone clays. Because of its general habitat, it seldom attains the great heights of E. regnans, although some trees of nearly 300' have been reported (Pearce Block). None over

PLATE 10 EUCALYPTUS REGNANS

(a) Old Tree-Andromeda Stand.

This is one of the rarer old trees in the Andromeda stand. It is probably about 400 years old. It is 55' girth and about 310' high (Abney). It is very unusual to find old trees in this area that haven't had their tops blown out. This implies a possible genetical factor such as resistance to stem decay in the 150-250' portion of the stem.



(b) Big Tree - Misery Block.

This tree is about 62' girth, and is the biggest yet found in the Florentine Valley. A tree with greater girth was recorded in the Tyenna Valley by Helms (1942).

250' were seen by the author. Girths are generally of the same order as for E. regnans. Volumes per acre are usually lower.

3. E. obliqua This species is generally associated with acid soils or dry rocky aspects on dolerite soils. It produces groundwood of relatively poor strength and colour. It produces a very important timber which, along with that of E. regnans and E. gigantea, is marketed as "Tasmanian Oak". Its timber is more durable than either of the other two "ashes". One tree of 285' was measured near the Andromeda E. regnans stand but it is generally rather shorter than E. regnans. Girths are comparable to the two other species.

4. E. viminalis This species is generally found on shallow, rather dry, dolerite solifluction deposits or other shallow soils over limestone. It sometimes grows to over 200' with girths up to 20'. A small percentage of E. viminalis wood is tolerated in groundwood pulp. It is not a popular sawmilling timber.

5. E. ovata (~~or possibly E. ovata x E. viminalis~~). In competition with E. regnans in Parker Block, this tree reaches well over 200'. It has similar qualities to E. viminalis and is most commonly found in small wet flats near the Florentine River.

6. Other Eucalypts Relatively unimportant here are the rare individuals of E. Johnstonii and E. globulus (at the Gap and at the Burma Road corner respectively), the peppermints E. simmondsii and E. amygdalina (on very acid soils), and E. coccifera (at altitudes above 3000'). More extensive areas of E. Johnstonii are now being opened up on top of Misery Plateau.

<u>PLATE 12</u> BIRD TRANSPORTATION OF ACACIA SEED

(a) <u>Regurgitation Pellet</u> This is a pellet dropped by a "Black Jay".

(b) <u>Same Pellet Dissected</u> This pellet contained nine Acacia seed. (Later found to be <u>Acacia melanoxylon</u>) The combination of a reasonable seed longevity of, say, 50 years with a pellet distribution of, say, 100 per acre per year would easily account for the appearance of Acacia species after burning old rainforest.

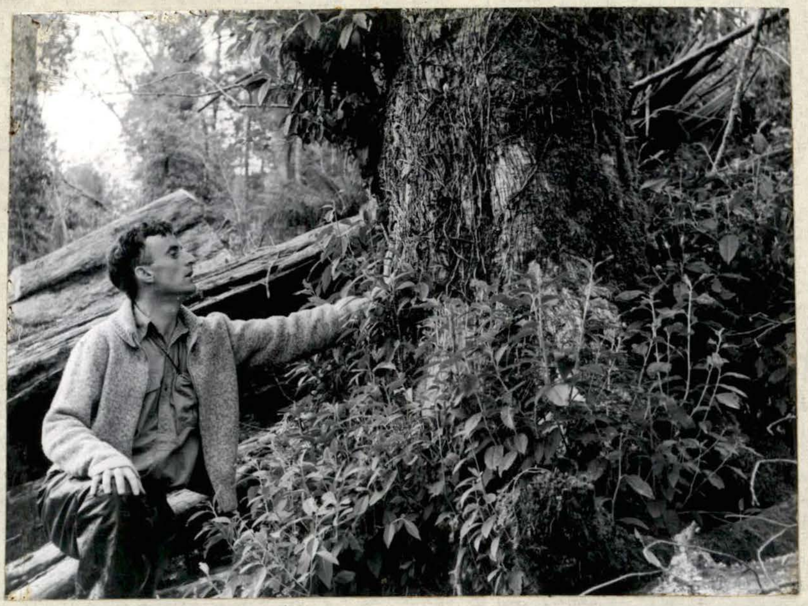
(b) Wet Sclerophyll Understorey Species

1. Acacia melanoxylon. This is an important timber tree in other areas, but is here generally found to be defective. It is probably the tallest of the wet sclerophyll understorey species (to 150') and some trees survive for at least 130 years after the regenerating fire. It is not found in dense stands in this area and it is slow growing compared to A.dealbata. ~~It~~Seeds from A.melanoxylon are distributed in space by birds and possibly by animals and in time by long term ground storage.

2. Acacia dealbata. This is the second tallest of the wet sclerophyll understorey species and one of the most abundant. It's timber is light and tough but is of no commercial value at present, however A.dealbata has great potential for pulpwood if certain technical difficulties can be overcome. This species grows as fast as E.regnans for the first 30 years and may live for more than 80 years. It is subject to serious defoliation by insects on some sites.

Gilbert (1958) suggested that the germination after fire of A.dealbata on sites not burnt for 350 years previously meant that the seed of the species had a longevity approaching 300 years. He doubted if transportation of seed by birds could account for this phenomenon. However one regurgitation from a black jay was found to contain 9 Acacia seeds. Although no further study was made of this subject it seems reasonable to suppose that 10 such regurgitations per acre per year, combined with a longevity of, say, 50 years would provide a store of 500 "spot sowings" of perhaps 5000 seeds per acre ready to germinate when old forest is burnt. In this way the marked difference in density of A.dealbata regeneration following the burning of old and young rainforest can easily be explained: the young rainforest has ground stored seed accumulated from both seed-fall and regurgitations even though the last tree may have died 20 years before, while the old rainforest has only 50 years accumulation of bird transported seed.

Plate 13 OLEARIA ARGOPHYLLA



(a) Large Olearia on the rainforest - wet sclerophyll boundary at S.18

(b) Olearia on the boundary between Athersoperma and Dicksonia on permian mudstone and Pomaderris on a limestone outcrop. The relatively frequent fires in the wet sclerophyll find nothing to burn under the Olearia and go out before reaching the rainforest understorey.

~~accumulation of bird transported seed~~. Seedling arising after fire often appear to come from several inches below the surface but I do not believe that so small a seed could live for over 50 years in the soil.

3. Pomaderris apetala. This species can form extremely dense thickets after fire if not severely browsed as a seedling. Pomaderris is a short slender tree seldom exceeding 6" diameter. Some individuals survive for 130 years but are not obviously bird transported. Pomaderris is conspicuously absent from the Styx Valley where old rainforest was burnt in 1934,'56,'59, and '61. It grows well on delerite solifluction soils and on limestone out-crops, but it can be found on all but the more acid soild.

4. Olearia argophylla. A short tree of no commercial value, O.argophylla attains a girth in excess of 3' and may live for over 250 years. It is especially conspicuous on limestone outcrops, rocky dolerite or rocky conglomerate sites. After fire it regenerates from both seed and coppice and continues to survive longer than any of the other species. of the wet sclerophyll understorey. It's seed is mostly wind dispersed and is probably short lived and not stored in the ground. Although Ashton (1956) showed that it requires very low light intensity to survive, seedlings have not been found in the dense forest here after a fire.

5. Zieria arborescens. This shrub or short tree lives for over 50 years. It is extremely abundant for the first 10 years after logging and burning most wet sclerophyll understory. It flowers and seeds from the age of 4 to 5 years onwards. The seed is stored in the soil for at least short periods and may be transported by birds.

6. Drimys aromatica A short tree associated with patches of "savannah" on shallow dolerite solifluction deposits. It is also found as a short shrub above 3000' on dolerite.

7. Phebalium squameum A moderately tall tree (to 100') which lives for over 120 years. The timber is yellowish, ~~and~~ close grained and suitable for turnery. The seed is stored in the ground for at least a few years. Phebalium forms dense thickets after fire in some areas and it is possibly an indicator of more acid soil although it grows on nearly all soils.

8. Pittosporum bicolour Although not as tall as Phebalium this tree has a whiter wood of similar quality and uses. It has an extremely scattered distribution, almost entirely attributable to birds, at least in this area. One seedling of this species has been seen growing well under fairly open old mixed forest canopy in the Styx Valley, otherwise it is ~~more~~ usually found in much more open country, often growing on the stems of Dicksonia antarctica

9. Leptospermum lanigerum This is the tallest of the "ti-trees", sometimes attaining 100' in height and 6' in girth. Its wood used to be popular for "jinker" poles. The best stems seen here are to be found in the Chrisp's area in association with Acacia melanoxylon and Eucryphia billardieri.

(c) Species of the Rainforest Vegetation

The species grouped under this heading have all been seen regenerating under a full canopy. Even so, stands of essentially one age are quite common for all these species - resulting from peaks of regeneration occurring soon after fire.

PLATE 14 ATHERSOPERMA MOSCHATA

(a) Fire damaged Atherosperma having shed most of it's leaves exposing the fine branching habit, straight stem and conical form.

(b) Multiple stems of Athersoperma of coppice origin following fire some 250 years ago.

1. Nothofagus Cunninghamii This is the tallest of all rainforest species in Tasmania and by far the largest. Trees 150' high and 30 to 33' g.b.h. were measured in Tim Shea Block. Smaller trees (16' to 20' g.b.h.) in the same area were 450 years old (same figure as obtained by Gilbert a few chains to N.W.). The tree's most important use is as a furniture timber, although research is at present being carried out at Boyer in an attempt to obtain satisfactory newsprint from it. It is already used for chemical pulps and hardboard by A.P.P.M.

The seeds are heavy and not readily wind dispersed due to poorly developed seed wings. There is a suggestion that some of the seed is water borne. Dense stands are often associated with dolerite soils especially at higher altitudes. On average clay soils, it is associated with Atherosperma, on cherty soils with Phyllocladus, on poorly drained dolerite with Eucryphia, and other ~~"depauperate"~~ rainforest species such as Anodopetalum. The Nothofagus-Atherosperma association is the most common throughout this area. Nothofagus regenerates from seed and, ~~coppice~~ after fire, from coppice.

It is less common on well drained ridges or on the valley floor in Lords and Parker Blocks, where almost pure Atherosperma understories have developed.

2. Atherosperma moschata This tree is not as tall or big as Nothofagus but it is perhaps more abundant in the rainforests of this area. It occasionally grows in pure stands in young rainforest, Otherwise, it is almost always associated with Nothofagus. On some sites, it appears to grow in association with Acacia dealbata (Lords, Parker, Gold Creek, Tim Shea, Road 4) for a few years. (In much the same way Nothofagus and Pomaderris are sometimes found to enjoy similar sites). Rare Atherosperma are found scattered through typical wet sclerophyll forest

of Westfield and Lords Blocks where they have obviously survived several fires. This ability to survive light fires is much greater than that of _Nothofagus_ or any other rainforest tree and it must be chiefly due to the remarkably clean floor developed under _Atherosperma_ making a humus fire impossible in many cases. Its seeds are wind dispersed over great distances. The ease of dispersal suggests that they do not particularly favour sites on dolerite soils which were available after fires 100 to 160 years ago but prefer mudstone or limestone soils. On shallow soils over rocky mudstone it appears to be more drought resistant than _Nothofagus_. If this resistance is general it may help to account for the scattered _Atherosperma_ in wet sclerophyll stands.

3. _Eucryphia billardieri_ In this area this species is practically limited to the slopes on Mt. Field Block. It is especially abundant in Chrisp's Block but occurs on wet dolerite solifluction soils on the Eastern sides of Tim Shea and Westfield Blocks. In parts of Chrisp's Block it seems to replace _Atherosperma_ in the usual _Nothofagus_-_Atherosperma_ association, especially under _E. obliqua_. It is a tree almost as tall as _Nothofagus_, taller than _Atherosperma_. Its wood was, for many years, used for axe handles, and is suitable for clothes pegs. Leatherwood honey is its most prized product today.

4. _Phyllocladus asplenifolius_ This is the only conifer of importance in this area although small patches of _Athrotaxis selagenoides_ occur under Wyld's Craig and Mt. Mueller. It is a tall tree, reaching 140' and girths over 6'. It is generally found growing on acid soils either over chert or quartzite or conglomerate, or in wet flats. It also occurs on shallow dolerite solifluction deposits where it is associated with _E. gigantea_. Otherwise, it is generally associated with _E. obliqua_ and

Nothofagus or Eucalyptus simmondsii.

5. Anodopetalum biglandulosum This tree occurs most commonly in the Styx Valley wherever open rainforest has developed on wetter, more acid soils. It is probably unable to compete for light in dense rainforest. It may be a true climax vegetation in some areas owing to the remarkable rate of litter decomposition that occurs under it.

(d) Ferns

Ferns form by far the greatest proportion of the tall herb flora. Only in the first few years after fire are other herbs such as the fire-weeds dominant. Only the important ground ferns are discussed here.

1. Pteridium aquilinum This fern, bracken, can be seen as extensive stands on many old mixed forest sites burnt in 1934. It also occurs as remnants under wet sclerophyll regeneration of the same vintage. Its spores have, like many of the ferns, a practically global distribution. These spores will apparently only develop on severely burnt seedbeds in the shade of stumps. Even though the spores must have moist shade to develop into the mature plant, this plant itself flourishes only where shade is practically absent.

Bracken appears to develop extensive stands only when a "breakdown" or "pause" occurs in the forest succession or cycle. This is especially noticeable on cleared lands in the Tyenna Valley where it represents the product of too frequent burning and/or too heavy grazing. Here it is only removed by mechanical disturbance of the soil. In the forest it is only removed by shade from the higher plants.

It is susceptible to frost and is seldom important above about 2000'.

PLATE 15 HISTIOPTERIS AND HYPOLEPIS

(a) Dense "wet ferns" three years after logging and burning old mixed forest. If not shaded out by trees and shrubs most of this cover will be succeeded by Pteridium. Without browsing and with enough tree and shrub regeneration this stage is by-passed (See experiment 77).

(b) Regeneration of Histiopteris rugosula following a creeping ground fire in old rainforest. Both "wet ferns" regenerate well both from spores and vegetatively.

It apparently takes the place of the wet sclerophyll understorey when old mixed forest or old rainforest is burnt. On these sites it is generally preceeded by the "wet ferns".

2. Histiopteris incisa and Hypolepis rugosula These two ferns will be discussed together under the term "wet ferns", this is because in this area both ferns occur in an intimate mixture on all but a few marginal sites. These ferns spring up abundantly after light fires and persist wherever there is shade. If the shade decreases, they are succeeded by bracken. If shade increases, they retreat to the more open, and more moist, gullies. Wet ferns also succeed bracken as it begins to be shaded out. "Wet ferns" are the most common "understorey" to the "Manfern" - Dicksonia.

3. Dicksonia antarctica This fern is particularly common throughout most of this area. It is favoured by gullies and possibly limestone clays and Atherosperma stands, but it can be found nearly anywhere except on extremely dry sites or at higher altitudes. It is most commonly found near or under E. regnans but can occur under almost any tall forest.

This plant seems to play a vital part in the ecology of this area. It germinates fairly readily from spores. It is extremely fire resistant (it is almost indestructible as far as natural fires are concerned). Even when burnt off at ground level after a ground fire the prostrate trunk continues to live and soon develops new contact with the ground, while the apical shoot just turns a right angle and develops a new vertical trunk. This trunk is a good seedbed for several tree species (especially Atherosperma). The seedlings become established on a shaded part of the stem and then establish their own contact with the ground by roots that run down the surface of the trunk. These

Plate 16 DICKSONIA AS A SEEDBED

This picture of an E.regnans - Atherosperma stand burnt in 1962 by a lightning fire demonstrates the special value of dicksonia as a seedbed for Atherosperma. The deformed tree in the middle of the picture started on the trunk of a Dicksonia now leaning over at about 45°. The Atherosperma roots grew down the stems of two touching Dicksonia to the ground. The vertical dicksonia has since died and rotted away.

The prevalence of this sort of Atherosperma establishment in this area, coupled with multiple stems derived from coppice suggest that the area was once dominated by ferns that burnt quite often. It appears that Dicksonia provides the explanation of how the forest recovers from such bracken areas as were produced by the 1934 fires in the old mixed forest of the Styx and Florentine valleys.

roots later become to all intents the lower 5 to 15' of the stem of the tree. This elevated seed bed appears to provide a major mechanism whereby the forest can recolonise bracken areas. This mechanism seems to be most important where there are relatively few eucalypts and no other tree species which are bracken's chief competitors.

The Dicksonia antarctica - "wet fern" association in "Manfern gullies" is remarkably stable in spite of fire. These gullies are naturally wetter than the slopes. They are continually shaded on the sides by much denser forest yet they have ample overhead lighting. The surrounding forests are from 100' to 200' taller than the manferns. This means that the gully climate is essentially that of a vertical walled canyon 100' to 200' deep. Because of this special climate and the non-flammable vegetation it develops this gully type burns only very rarely even when both sides of it are alight. Even when it does burn, the fire is very light and the ferns regenerate far too rapidly for it to be invaded by the surrounding forest. Even the few seedlings that do survive the intense early competition with the ferns are generally wind thrown if they reach any size because of a high winter water-table, soft soil and weak root development.

This fern flora in the "Manfern gullies" is possibly the only true climatic climax in this area. If this is true, it is only preserved by the fire seres on both sides.

4. Polystichum proliferum This fern is most commonly found under wet sclerophyll forest. It recovers from fire almost as well and in much the same way as Dicksonia. It appears to favour drier sites than the latter, leaving the wetter sites to the "wet ferns". If an area is left too long without fire, it tends to die out, probably due to increasing shade. In this case, it is doubtful whether anything but litter succeeds it. It regenerates by spores and vegetatively. This second method consists of the

development of a small fern plant near the end of the frond which takes root as the frond droops and dies.

5. Blechnum procerum This fern is more commonly associated with E. gigantea and E. obliqua forests. It is somewhat uncommon under E. regnans. It appears to favour moist, acid soils. It is not a pioneer but regenerates fairly well under shady conditions. Regeneration appears to be chiefly by means of spores.

SUMMARY OF PART IA.

1. The climate appears to have been reasonably constant since records were commenced. A possible increase in rainfall at the turn of the century in N.W. Tasmania is somewhat compensated for by a possible decrease since about 1930.

2. The heavy yellow and pink clays of limestone origin on the floor of the Florentine Valley are the product of waterlogged conditions that no longer exist there today. Drainage of the Gordon Valley, where these soils are still being produced, would allow the development of excellent forest on what is now a tree-less plain.

3. Further support is given to Jenning's hypothesis that the Florentine drainage has been entirely reversed.

4. The Dolerite-origin deposits associated with Lawrence's Creek are of three sorts:- Till near Lawrence's Creek Bridge, solifluction "streams" on the ridges to the North and South of the Creek, and river gravels in the bed of the creek deposited at the end of the glaciation.

5. All tree species are, for convenience, allocated to one of the two important vegetation~~s~~ types, Wet Sclerophyll and con Rainforest. The vegetative types found in the forests of this area are "Pure Wet Sclerophyll","Pure Rainforest" or a mixture of both. This mixing is not the prerogative of the eucalypts. However, their superior longevity to the wet sclerophyll species ensures that they are present in nearly all mixtures ("Mixed Forest").

6. <u>Ac. dealbata</u> seed is bird-transported and need therefore have a longevity of as little as 50 years to explain it's presence when old Mixed Forest is burnt. It is doubted if so small a seed could remain viable for much longer than 50 years.

7. Pomaderris trees live for 130 years or longer. Ac. dealbata lives for 100 years in some places.

8. Pteridium appears to colonise areas that are undergoing an "ecological pause".

9. Dicksonia antarctica may form the only true "climax" association in the form of "man-fern gullies". It may also be instrumental in the recovery of a site from Pteridium.

PART IB - FIRE

Fires in Tasmania have occurred throughout a very long period. This is assumed because of the general cover of Eucalypts, most of which appear to require fire if they are to regenerate.

The three important Eucalypts in this area all produce well marked annual rings. This enables the construction of an approximate fire history of the area over the last 400 years (no eucalypts have so far been found over 450 years old). Not only the Eucalypts, but most other tree species in this area produce annual rings. However, the Eucalypts have the advantage of being ubiquitous and of regenerating within a year or two of the fire.

FIRE HISTORY

Ring Counts Generally three counts were made per coupe or group of coupes for the Coupe Register. In all, 255 careful counts were made on 80 areas averaging 50 acres each. Allowance was made for stump height (3' per year), occasional summer rings, and time since felling. Even so, it was realised that errors of up to 10 years could occur - especially in the older trees.

The distribution of ages of Eucalypts counted in the Styx and Florentine Valleys is as follows :-

Fire Date	Age (1960)	Period	Styx	Florentine	Total
1500-1600	360-460	100	16	4	20
1600-1700	260-360	100	27	12	39
1700-1780	180-260	80	2	22	28
1780-1840	120-180	60	1	157	158
1840-1900	60-120	60	1	9	10
Total to 1900			51	204	255

The table should be interpreted with some reserve because of the following trends :-

1. Logging is often concentrated in areas of young timber,
2. More logging has been done in the Florentine than in the Styx,
3. Rings are easier to count on young trees,
4. Trees under 100 years old have seldom been logged,
5. Eucalypts seldom live longer than 350 to 450 years.

However, the one obvious finding is that the Styx forests sampled appear to be mostly over 250 years old and the Florentine forests mostly under 200 years old. In the Florentine, very large spar-aged stands appear to have arisen between 120 and 180 years ago. Despite every care taken over ring counts, no peak years of occurrence are discernable. However, 1826, 1815, 1810, 1806, 1795, 1785 are all very low points in the ring count histogramme. At least one important fire occurred about 90 to 110 years ago and spread over most of the drier soils of the Florentine, but it was relatively light, did little damage to existing trees and produced few stands now merchantable.

Many suppressed eucalypts and young Nothofagus bear witness to it especially in Lords and Westfield Blocks. A fire at about the same time was the last fire to burn over the mudstone and limestone clays between Mt. Tim Shea and Wherrett's Lookout and is responsible for the excellent Atherosperma stands there. Similar stands of Atherosperma in Gold Creek Block suggest that another fire occurred there about the same time, but if so, it did not spread any further into the Styx Valley.

The range in Lord's Block ring counts is not entirely due to inaccuracies. Several distinct fires definitely occurred. In most spar stands in this area there is often an obvious discrepancy between the age of the bigger spars and that of the understorey. Even where rainforest understorey predominates it is often found to contain Pomaderris trees with clear ring counts showing that the understorey is younger than the bigger eucalypts. Under the bigger eucalypts there are often numerous smaller stems and certain parts of a coupe will have smaller sized dominants giving smaller counts and which cannot be attributed to site differences. This suggests that several fires occurred over the 80 year period.

Two touching trees on L.25 were counted in 1957. One gave 155 rings, the other 171 rings. The older tree had a marked gum vein on the side adjacent to the younger tree 156 rings in from the edge. Three other trees in this area had 171, 171 and 169 rings.

Two trees on L.22, just east of the Settlement area just South of Dawson's Road, were felled in 1957. They showed gum veins for the following years :-

1. Age 136 years - 1889, 1882, 1871, 1869, 1861, 1859, 1857, 1855, 1853.
2. Age 136 years - 1859, 1857, 1855, 1853, 1851, 1849, 1847.

Yet practically nowhere else were fires recorded for these dates. Moreover, the two-year periodicity makes it very likely that these gum veins were caused by man-made bracken or grass fires and that the fires were light. It is interesting to note that the Dawson's Road was put through in 1847.

The most likely explanation of the various Lord's fire ages is that aboriginal man and lightning was responsible for many of the fires between 1780 and 1840 and white man and lightning for most of the fires since.

Fire Weather If it is accepted that fire is, and was, ever-present in Tasmania, what sort of weather produces the sort of "fire year" that 1934 was ?

In the Northern end of the Florentine Valley, 1934 was a bad fire year, but 1959 produced a much hotter fire, even though the ground there had apparently been drier in 1934. (Marshy patches were burnt in 1934, and NOT in 1959; excellent *E. regnans* spar stands between the marshy patches were burnt but undamaged in 1934, but killed in 1959 - Misery and Jungle Blocks).

1961 was drier than 1934, or at least as dry, but neither year was as hot as 1959. 1934 was more windy than 1961. The drought in 1933-34 started one month earlier than in 1960-61 (See Table 3).

It is reasonable to assume that without the control of man, or with more wind, as great an area may have burnt in 1961 as in 1934.

It has been suggested that occasional years of catastrophic climate are to blame for the stands of Eucalypts in this area. More likely the explanation is one of the chance occurrence, together of several factors, at least one of which can be partly controlled by man (5), and one is entirely dictated by vegetation and man (4). (see list below).

1. A very dry summer after an average winter (1934, 1961).
2. A dry summer after a very dry winter (1950).
3. Several days of high wind from a Northerly direction (1934, 1959).
4. Extensive areas of dry fuel.
5. Early (e.g. November) ignition and no control (1934).
6. Several days of higher than average temperatures (1934, 1959).

Means of Ignition

(i) Man Man may be the most important fire lighter for the State as a whole, but he is not the only one. Jackson has shown that fire and aboriginal man were inseparable and says that fire was present in Tasmania for thousands of years because of this. But man cannot be entirely blamed for the extent of such widespread fires as occurred in 1934. He probably lit only as many in 1934 as in other years but their spread was carried out by extreme fire weather conditions, combined with extensive fuel accumulations. Once fire starts in such conditions, it only requires a hot windy day to spawn a thousand more fires ahead of it.

(ii) Spot Fires No records have been kept here specifically dealing with spot fires. However, it appears certain that they can occur on almost any hot, windy day in summer. To become fires, ~~these~~ sparks must land, while still glowing, on dry fuel. The first condition is controlled by the weather, the second by the vegetation and the fuel it produces. The vegetation also plays a vital part in producing these sparks. It plays its most important part in producing fuel at high levels where the wind can get at the fire, and in producing "fuel lines" of inflammable material from the ground to the tree tops. The most striking examples of "fuel lines" are found in the stringybark eucalypts. Fuel at high levels generally consists of dry stags, aerial mosses, lichens and less often the live foliage of the tree crowns (in crown fires).

The most striking evidence of the regularity of spot fires in this area is to be found in the Styx (S.18). The significance of this evidence is fully discussed in Section C of Part I of this thesis. However, it is sufficient to say here that S.18 proves the xxxxxxf regular occurrance of spot fires at one place. That they also occur in many places is common knowledge.

The distance ahead of the main fire that spot fires can occur is subject to much argument. In 1959, spot fires occurred 2-3 miles ahead of the fire. The 1934 fire is reported to have "leapt from Tim Shea to Abbott's Lookout" (about 12 miles). The 1960 Tyenna Peak fire spawned a fire at least one mile to the West at about midnight. In all cases it appears that the places the spot fires start are on especially dry sites having a more inflammable vegetation (dead or alive) than their neighbours.

(iii) Lightning Fires (see also under Climate) The lightning fires that have occurred in this area since 1950 were generally of minor extent. But the 1950 fire at the Florentine Depot would probably, and the 1961 and 1962 fires would definitely, have spread if they had not been controlled by man. Without man's interference the latter fires would probably have completed the destruction and regeneration of the old mixed forests of the Styx Valley that the 1934 fire started.

The only aboriginal legend that has reached us is that "fire came as a star from heaven" (FLETCHER 1957). This can only be interpreted as lightning fires. Not just lightning strike. It is reasonable to assume that they have always been part of the environment. It is likely that they occurred more frequently in the drier parts of Tasmania or were at least randomly distributed over the State. (If they are not randomly distributed, but are more frequent on certain sites, then they are just an additional factor peculiar to the site).

Distribution of Fire in Time and Space.

The aborigines seldom went into the dense forest (see Section C). They lived, hunted and lit fires in the open country. Open country was either dry, or if wet, was open because of lack of drainage, lack of fertility or too frequent fire. But the dry country, the wet plains, and the barren hills were only open because of fire. Without fire, all these types produce a nearly impassable thicket.

All lands, with less than about 35" rainfall, and most of the West Coast plains and ranges, were open when white man came. Aboriginal man had no trouble burning these types.

This means that the dense forest was regularly surrounded by fire at very frequent intervals. But it only burnt infrequently.

It is true that the location of the boundary between the fertile Eastern and the barren Western geological formations is conveniently parallel to the fire winds. It is also true that the general orientation of the 40" to 70" isohyets is somewhat similarly placed.

This means that most of Tasmania's dense forest is in one massive lump protected to the East and West and having no major open country fire source between it and the dangerous fire winds from the North. From this it could be argued that within these bounds lightning fire and chance control the pattern of fire and that they entirely explain it. But the pattern of fire within this area is also the pattern of vegetation. Moreover, the pattern of vegetation is the pattern of sites. It is not a random pattern. There is every reason think that a chance pattern of fire behaviour is not important in explaining the pattern of vegetation. Fires in the dense forest are controlled by some factor. The most likely factor is fuel which, in turn, is controlled by vegetation and site. Vegetation is also controlled by the site.

The Effect of Fire on Measurement of "Site"

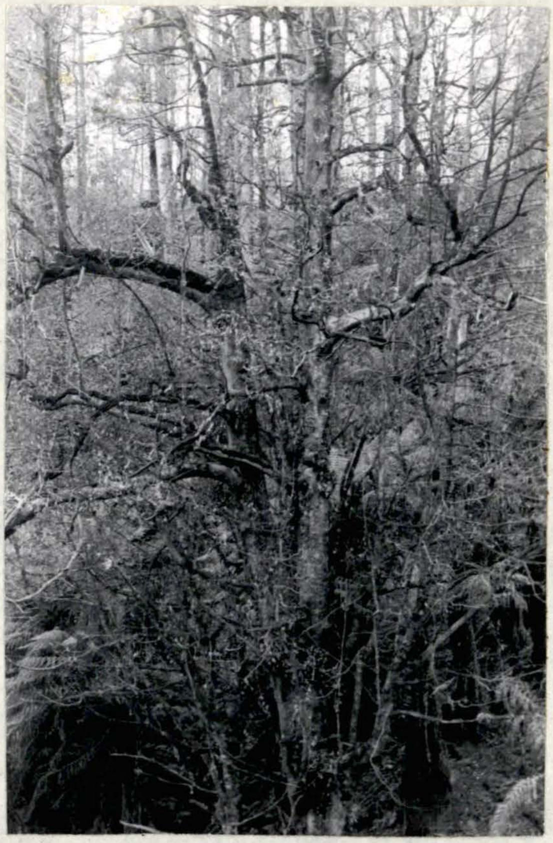
When discussing the environment of a particular area the term "site" is used to indicate the sum of the environmental factors. To avoid unnecessary argument caused by differing concepts of "site" the term will be discussed and the assessment of "site" be defined.

The most obvious measure of qualities of the site is the vegetation it carries. It is considered that two areas having very similar vegetations have similar sites. This can happen when the areas have obvious differences such as topography and aspect. Conversely, when areas have different vegetations (and when their differences are not just a matter of age since the last fire) they must be considered as having different sites however similar they may appear in geology, aspect, topography, rainfall etc.

Unfortunately where fire is apparently an integral part of the environment similar sites can have similar vegetations but at different times. This difficulty may be overcome by projecting the present vegetation forward in time and estimating the "fire climax" of the site. However there is a tendency to project to the "climatic climax" and then modify this projection by the words "if protected from fire". This thesis favours fire as an integral and recurring part of the environment and therefore cannot agree to long projections except where there is evidence that the site is not burnt often (e.g. fire-killed old rainforest). This attitude will be discussed fully in Section "C".

For present purposes "site" is defined as being measured by the vegetation present if it is in a mature state, or by a projection of a young vegetation only as far as evidence on that site will allow. This is believed to be approximately equivalent to measurement of the site in terms of its "fire climax".

PLATE 17 THE SPOT-FIRE MECHANISM



(a) 250 year old <u>Atherosperma</u> showing heavy accumulation of moss on limbs. (Tree fire damaged causing leaf shed, moss on most limbs burnt away, 1962 lightning Fire Styx Valley)

It is this type of fuel that supplies the aerial sparks on one tree and helps to ensure these sparks cause fire on the next.

(b) 450 plus year old <u>Nothofagus</u> burnt by a fire which was started by sparks igniting the rotten wood and moss and lichens in it's crown. Fragments of burning wood ignited a humus fire which in turn eventually felled the tree.

Types of Fire

In most forests there are at least three types of fire, ground, surface and crown fires.

Ground fires occurred over large areas of the Styx and Florentine in 1934 and in Misery and Jungle Blocks in 1959.

Surface fires can occur in any year with, or without, a ground fire.

Crown fires can occur only where there is wind combined with almost continuous fuel at crown level or with numerous "fuel lines" between the surface and the crowns. No examples of crown fire have been found by the Author in rainforest, nor in pure E.regnans crowns. Crown fire is most common in dry-sclerophyll understorey such as Pultanea spp and in the stringy-barked eucalypts, especially E.obliqua.

The 1934 Fire in the Styx Valley.

If crown fires did not consume the Styx forests in 1934, what did? Under dense old rainforest canopy, it is almost certain that ground fires could not burn fast enough to travel from Mt. Tim Shea to the Snowy Range in one summer. There is insufficient wind on the forest floor to accomplish this feat by either ground or surface fires. Apparently the fire spread by the joining-up of millions of spot fires started from sparks that originated in Eucalypt stags and dry old Nothofagus crowns. These sparks were wind carried ahead of the fire to ignite other stags and especially to light up the aerial moss carried by old rainforest trees. Even so, this was not a crown fire. The foliage of the rainforest trees was consumed only where it was very close to a fiercely burning stag (or when the tree was felled by ground fire). These tree-top fires showered sparks onto the dry humus layer and started numerous ground fires. It was the ground fires that killed the Styx rainforest in 1934. It was not slash, or understorey crown fire, although such fires were certainly responsible for the death of much E. regnans in Westfield Block that year and in Jungle Block in 1959.

Observations of the rainforest killed by the 1959 fire showed that the crowns were whole but dead.

The spot fire dispersal mechanism to a large extent explains the pattern of the 1934 fire in the Styx Valley. Where it lies in the shelter of the Maydena Range the forest is unburnt. To the East and West it is burnt. Yet the Maydena Range is topped by a plain that was burnt in 1934. However, this plain is not like the valley plains because it is bordered to the South by short young rainforest which did not burn in 1934. The other plains grade through highly inflammable dry sclerophyll type vegetation to E. obliqua. This means that all plains but the Maydena plain produced an intense fire that was readily carried up into the wind. The Maydena Plain actually acted as a fire break, but only in conjunction with the rainforest edge. The plain brought the fire down to ground level, the young rainforest edge put it out. Note also that the old rainforest burned in 1934 - the young rainforest did not.

Fire Susceptibility Spot fires only start on suitable dry fuel. When they run out of this sort of fuel they go out. By this means dry sites or vegetation such as the wet sclerophyll E. obliqua, E. regnans patch on S.18 were burnt regularly by fires which did not burn the surrounding rainforest. It cannot be that this patch regularly received the only live spark. It was, however, the only patch receptive to live sparks. But the vegetation which was so receptive was a product of a dry site (in this case conglomerate outcrop).

Very little of the 1934 fire-killed rainforest is on conglomerate, almost all of it is on mudstone, all of it was old. Young rainforest on mudstone in the Florentine was an effective fire-break in 1934.

This suggests that fire susceptibility may be a function of two factors :-

1. The vegetation produced by a given site,
2. The age of the vegetation.

It also suggests that fires which start in a susceptible vegetation tend to go out where the ~~relative~~ fire susceptibility of the vegetation decreases.

Gilbert (1958) explained the relative infrequency of fire at the Southern end of the Florentine as being due to its greater distance from the fire source. But mixed forest extends from the South right up to the East of the supposed fire source - "the Settlement". Moreover, the mixed forest is all uphill of the fires that burnt the floor of the valley. With the wind behind them, and the slope in their favour, fires should have regularly burnt the Western slopes of the Misery Range and the Mt. Field Block. <u>In fact, they regularly burnt all but this slope</u>. In terms of site, and vegetation, the explanation is obvious :-

1. The fires were principally on the ground, or came down to the ground when they met the mixed forest.
2. Wind had little control on forest fires on the ground.
3. Wind did not control the fires in the mixed forest.
4. Changes in site (limestone to mudstone), and accompanying changes in vegetation, prevented fires spreading to the East.
5. Changes in site (climate) prevented the fires spreading to the South and either East or West. (Rainfall increases about 15" from the Settlement to Tim Shea and probably as much from the valley floor to the top of the Misery Plateau.)

Fire Behaviour (Unless otherwise stated, this section deals with fire not aggravated by fuels prepared by man, especially logging slash).

If spot or lightning fires occurred in any one area every summer, the type of vegetation would control their chance of spreading :-

a. Vegetations that produce ample dry and green fuel
These are able to support a fierce surface fire or an understorey crown fire, but generally develop little humus. (In order of inflammability). The fuels developed are open to the wind.

	Minimum period between fires
1. Grasslands	1 year
2. Bracken	3 years
3. Dry sclerophyll Shrub layer (Zerophytic shrubs)	3 - 10 years (Epacrids etc., also Button Grass Plains)

b. Vegetations that produce little dry and no green fuel
These do not support a fierce surface fire, except in small patches of litter under Eucalypts. Moreover, understorey crown fires are less common than in (a). Generally these will carry a very light surface fire. Humus development is slight. Fuels are moderately well protected from the wind.

4. Wet sclerophyll (Mesophytic shrubs).	10 - 20 years (Pomaderris etc.)

c. Rainforest and Mixed Forest As for (b), but with crown fires unknown. Humus development is variable but is generally greater than for (a) or (b), especially with time. Practically all fire damage is caused by creeping humus fire started from spot fires which occur in stags, aerial mosses, stringy-barked Eucalypts etc. Ground fuels are out of the wind altogether. Development of aerial fuels occurs with age.

5. Old mixed forest - ANY VERY DRY YEAR.
6. Old rainforest - ANY VERY DRY YEAR.
7. Young mixed forest - In <u>extraordinarily</u> dry years or only around the Eucalypts.
8. Wet fern gullies - In very dry years, then only lightly.
9. Young rainforest - Practically unburnable, unless growing on a very acid site and/or having accumulated much humus at an early age (e.g. <u>Nothofagus</u>/<u>Phyllocladis</u> or <u>Pure Nothofagus</u> in some areas.)

Fires in type (a) are affected more by <u>temperature</u> and <u>wind</u> than ground moisture. Fires in type (c) are affected almost entirely by moisture of the humus layer, but are dependant on <u>wind</u> and probably temperature for spot-fire ignition.

Fires in type (b) are likely to crown only on very hot or very windy days.

<u>Examples</u> seen in this area :-

(a) <u>Dry sclerophyll fires</u> Northern half of Jungle Block, Westerway Gorge, Button Grass Plains.

(b) <u>Wet sclerophyll fires</u>

(i) <u>Light Slash fires</u> 1934 P18, 19, 20, 21, L.6, 22, 37, Misery, Westfield Block. 1959 Misery 8, M2.

(ii) <u>Crown fires</u> 1934 W10 quarry, L's Ck. gravels. 1959 Jungle Block.

(c) <u>Old Mixed Forest</u> - Styx Valley - All 1934 fire areas.
<u>Old Rainforest</u> - Pagoda 1961, Tim Shea (N. and W. of Pagoda) 1934.
<u>Young Mixed Forest</u> - W.47, T/S "C"1, both 1934, Rd.4, L25 (100 to 160 years ago).
<u>Fern Gullies</u> - Diogenes Block, Gold Ck. - Jubilee boundary both 1934.

Young Rainforest - Chert ridges in Westfield 1934. Spot fire on Wherrett's L.O. in 1961 (Conglomerate). Both with much Phyllocladus and deep humus.

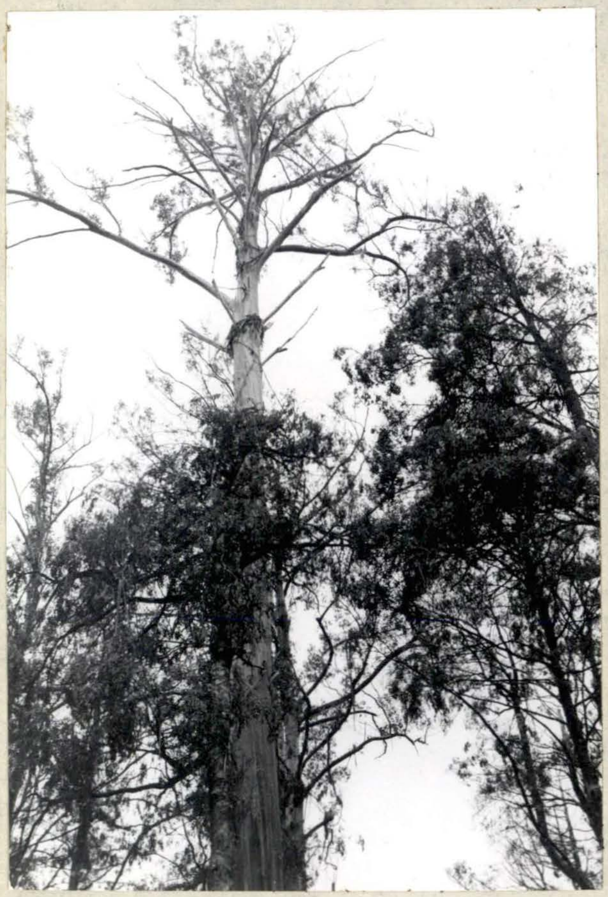
N.B. This pattern is greatly modified where the forest is first disturbed by man. Even young rainforest burns in dry years where logging slash occurs or where the forest floor is exposed to the sun on Southern and Eastern road edges, (1960 and 1961).

Examples of the old pure rainforest burning are few because this type is fairly rare here. Some occur on deep limestone clays in Tim Shea Block. The only part relatively undisturbed by man was spot burnt in 1961, however, it was only patchily burnt by a ground fire probably because of the short period of fire season left after the spot fires occurred in mid-March.

In 1934, the old rainforest was killed for only a chain or less around the edges where fire came off the chert ridge, whereas the old mixed forest was destroyed over thousands of acres.

Generally extreme fire conditions do not occur in one area every year so that types 1, 2, 3, or even 4, may wait several years before being burnt, but wet sclerophyll, mixed forests and rainforests, are, for many years, in a receptive state and spot fire conditions probably occur at least once every 20 to 50 years in any area.

Plate 18 LEAF LITTER AND SHADE WHEN RAINFOREST BURNS



The leaf litter is an average sample of Atherosperma following the 1962 Styx lightning fire. Note how the Dicksonia trunk sheds the falling leaves and has allowed a few Acacia seeds to germinate.

The trees under the fire-damaged E.regnans are dead Nothofagus. The fire occurred in January 1959. The picture was taken in April 1962. The light conditions both sides of this patch were caused by logging. Without man's disturbance, the shade from the dead Nothofagus would have prevented all but a fraction of the E.regnans seed shed from developing into trees.

PLATE 19 THE EFFECTS OF FIRE ON THE VEGETATION

(a) Fire killed rainforest regenerating to rainforest with the only addition being Ac.dealbata. The fire was in 1934 when the rainforest was about 350 years old. It will only be another 50-100 years before the last Acacia dies and pure rainforest regains the site. Note the E.regnans regrowth under fire killed parents further up the slope. There is no evidence of any encroachment by the eucalypts as a result of the fire.

(b) Fire burnt both sides of this picture in 1959. Where it burnt mixed forest on the left only wet ferns are regenerating with some coppice from the Nothofagus. It is likely that further rainforest regeneration will follow. No wet sclerophyll regeneration occurred after the fire on this side and none can now be expected.

The Effects of Fire on the Vegetation

Three types of fire in the several types of vegetation produce different sorts of seed bed and light conditions, e.g.:-

Grass, Bracken and Dry Sclerophyll burn to produce a clean seed bed free of litter with ample light.

Wet Sclerophyll burns to produce a seed-bed covered by 50 to 100% leaf litter after the fire except where the Eucalypt forest has also been crown-fired. In the latter case, light and seed-bed are optimum. ~~In the former, the more usual case,~~ Light is hardly affected if the fire is only on the surface, and is increased to about 50% of daylight if the understorey is crown-fired. However, both types of fire produce an enormous cover of leaf litter from either the understorey or the eucalypts.

Mixed Forest and Rainforest burn to produce relatively little increase in light on the forest floor until the dead leaves begin to fall. Atherosperma leaves falls in a few days, but the Nothofagus leaves may stay on for years. The seedbed is subsequently almost entirely covered by leaf litter. Where fern gullies are lightly burnt the seedbed is rapidly re-covered by ferns within six months of the fire.

Regeneration under these various conditions is closely related to the previous vegetation. Seeds of the trees present are shed onto the seedbed, but are often shed before the leaves and then covered by them. Seeds ~~of some previous species~~ stored in the soil, germinate and push their shoots to the surface. Seeds of other species are carried in by wind (or water, animal or bird activity). The seedbed and light resulting from the fire are products of the way the fire burned. This is controlled chiefly by the previous vegetation.

Summary of Part 1B.

1. Forestfires have occurred at fairly regular intervals for thousands of years.

2. Several fires not associated with logging occurred in the Florentine 120-180 years ago with relatively few for a long time before or after.

3. Great fire-years are not necessarily the product of years of catastrophic climate. They are the product of normal variations in the climate, and accumulation of fuel which is the product of the vegetation.

4. Man, lightning and burning embers carried by the wind from nearby fires (i.e. Spot fire) are the main means of ignition. But aboriginal man is unlikely to have lit many fires in the dense forest.

5. Lightning, and spot-fires (from fires lit by man or lightning in the open lands), have always provided regular means of ignition in the dense forest. Isolated patches of drier vegetation on drier sites ~~manage~~ to burn frequently in surroundings which burn only occasionally.

6. Ground fire probably does the killing of the trees when undisturbed old rainforest or old mixed forest burns. But this sort of fire spreads slowly. Spot fires probably provided a mass start for a million ground fires when the Styx forest burnt in 1934.

7. Fires tend to go out at or near the same boundary until the vegetation over that boundary is ready to burn. (This does not hold true if man has been upsetting the natural pattern of fuel development).

Summary of Part 1B. (cont)

8. Without logging, a definite but different fire frequency rules in each vegetation type. The vegetation does not burn before a given age but later develops fuel that will allow fire to destroy (most of) it any time a spark happens to land in suitable weather conditions.

9. Without man's interference, fire burns in a certain way in each vegetation. The vegetation and its litter largely control how the fire burns.

10. Rainforest burns quietly to produce a shady dead stand which favours its own regeneration from seed or coppice.

PART I C. TREND AND EQUILIBRIUM IN THE ECOLOGY

Introduction

The terms commonly used to describe ecological trend and equilibrium are "succession" and "climax". These terms have somewhat ambiguous meanings when applied to Tasmanian vegetation and to avoid confusion with accepted concepts in Northern Hemisphere ecology, the two terms will be qualified wherever used.

Observations in mixed rainforest - eucalypt forest in the Florentine area appear to permit an alternative interpretation of the ecology to that propounded by Gilbert (1959) and Jackson (1956 - unpublished).

Gilbert and Jackson recognise that the effect of fire cannot be excluded from an analysis of Tasmanian vegetation. Both discuss the frequency of fire and its effect on the vegetation, relating certain vegetations to certain frequencies. But they convey the impression that the relationship depends wholly on fire; that the frequency of fire controls the vegetation. They relate the vegetation to the site and the frequency of fire to the site. But they regard the arrival of fire at any one site as determined by man. They say that practically all fires are man-made, and then go on to imply that these fires can only travel as a continuous front.

Both authors overlooked or discounted three important factors. These are fires caused by lightning, secondary fires caused by sparks (commonly called "spot fires"), and the pattern of fuel accumulation.

Gilbert and Jackson both concluded that there was a trend apparent in the vegetation, that this trend applied to so much of the state that the explanation must include a changing or recently changed climate.

My observations suggest that the vegetation of much of Tasmania is in dynamic equilibrium with the environment, and that current or recent changes in climate need not be invoked to explain any vegetation in the state. It will be proposed that the vegetative equilibrium is maintained by fire, the distribution of which is largely determined by the fuel that the vegetation produces.

Ecological Equilibrium

The environment is made up of numerous factors, practically all of which are in a state of flux. If the environment is in equilibrium this equilibrium must necessarily be dynamic. It is likely that the vegetation in such an environment is also in dynamic equilibrium. Should the environment change it is believed that the vegetation would adjust to that change after only a few generations. Following the climatic change that occurred at the end of the last glaciation it is conjectured that only one or two thousand years were required for the vegetation to reach equilibrium with the climate. On the other hand soil characters would probably take much longer to approach a climax state. It is further suggested that the fluctuations in the climate since the last glaciation are insignificant compared to the change that occurred at the end of the glaciation.

If these assumptions are reasonable it could be considered that all the factors of the environment, except man and soil, are in equilibrium. If the changes in the soil are imperceptible there should be evidence of stability where man's effect has not changed. Evidence of trend or succession should be most obvious where man's effect has changed most markedly.

Evidence either way is very hard to evaluate. How can changes within a dynamic equilibrium be distinguished from those of a system not in equilibrium?

What changes in the environment would be required to convert a dynamic equilibrium into a trend?

What are the important changes known to have occurred in the last few thousand years?

Are these known changes sufficient in themselves to account for current anomolies?

These are the basic questions to be answered if the ecological balance or imbalance is to be assessed.

<u>Known Changes in the Environment</u> (a) <u>Climate</u>

The last glaciation in Tasmania occurred over 15,000 years ago. The sea level was rising from 12,000 to 6,000 years ago. The sea level has been relatively constant for the last 6,000 years. This relatively constant sea level indicates that any climatic changes that have occurred in the last 6,000 years have been relatively minor or local (Davies 1962).

One most important fact about climate is that seasonal fluctuations are very great when compared with annual fluctuations. If the weather experienced in any winter were to last throughout the year much of the island would soon be permanently covered by snow. Even now where the annual rainfall is over 100" there are several days in most years when certain ages of all vegetations will burn.

Practically all vegetations in Tasmania are not only capable of surviving normal fluctuations of weather on one site but also have wide ranges in terms of annual rainfall.

Where fire is recognised as an integral part of the environment the vegetation is invariably most efficiently regenerated by fire. Once regenerated the vegetation is apparently capable of surviving such a variety of weather that minor fluctuations of the climate become very much less important than has been suggested (Jackson 1956).

Because of fire and vegetative tolerance of wide ranges of climatic conditions, it is considered that only the major climatic change prior to 6,000 years ago should be used in explanation of current ecological systems. Only where this known severe change fails to explain the ecology should subsequent minor changes of climate be considered.

Known Changes in the Environment (b) Man

The most important changes in man's effect on the environment occurred with the coming of white man about 1800, and with the removal of the Tasmanian aborigine by 1830. These two factors amounted to a change from a small, nomadic but probably constant population, to an increasingly large but settled population.

The major effect on the vegetation was the change in distribution of man-made fires in both time and space. Aboriginal man burnt widely and very frequently. White man probably burnt more locally, more irregularly, in many places less frequently, and in a few places more frequently. White man's more frequent fires were only brought about by his ability to produce fuel soon after the previous fire. This fuel came from clearing operations or from extensions of grasslands and their annually available fuel.

White man's less frequent burning occurred in those areas furthest away from the settled areas, generally at higher altitudes, at higher rainfalls, and on the infertile West Coast.

In some areas there was probably no change because these areas are notoriously inhospitable to animal life in general and to man in particular. These were the areas of dense forest. These forests are characterised by a dense wet sclerophyll or rainforest understorey; by a general lack of feed for game; and a disinclination to be burnt again soon after a fire. It appears that aboriginal man only passed through these dense forests of necessity to get from one plain to the next. He lacked the equipment to keep many tracks open. Neither was he able to prepare much cut fuel with his stone tools.

It is believed that regular aboriginal activity in the valleys of the Florentine, Tyenna and Styx Rivers was confined to the major plains. However much of the dense forest of these valleys may have been traversed in the short period of good accessibility that occurred after the infrequent fires.

Evidence of Succession

The best evidence of succession is that which proves that a given site now carries a different vegetation to that which it used to carry and that the previous vegetation could not reasonably be expected to return by any natural means.

Some examples of such evidence are listed below.

(a) Surrey Hills On the Surrey Hills plateau country there are several thousand acres of rain forest about 150 years old. There is every indication that this forest has arisen following a rapid succession from Poa grass plains, through Drimys shrub savannah to Nothofagus rain-forest (all types with or without E. gigantea). Needham (1957) suggested that the Poa plains represented the stage in the fire cycle after the rainforest had been destroyed by fire. However regeneration surveys of cut-over young rainforest in this area showed that it was unlikely that the rather milder effects of wild fire could produce any grass at all. Only a dense layer of wet ferns developed after logging. These ferns showed no sign of ill health and looked quite capable of surviving until the forest again closed over them.

Needham (1960) later suggested that the change was the result of a 10" increase in rainfall over the last 75 years. However, rainforest grows just as well with a rainfall of 80" as it does with 90" and even with this increase it would almost certainly be possible to burn *Poa* plains every year. Even if this amazing jump of 10" actually did occur (see earlier) it is unnecessary to look for a reason why rainforest then started to grow, all we have to find out is what was preventing it growing before on such an excellent site for such a long time.

The most likely answer is fire; regular fire over hundreds of years with possibly less than 10 years between fires on any one area. Fire can account for the perpetuation of the plains on these soils but it seems insufficient to account for their origin.

(b) *Camden Area* Ellis (1963) working in the Camden area of North East Tasmania, found an active succession from *Poa* through *Persoonia gunnii* and *Drimys* to *Nothofagus* accompanied by a marked decline and wholesale death of the *E. gigantea* overstorey. He attributed the effect to a decrease in the number of fires in the area which enabled the less inflammable shrubs to encroach on and succeed the *Poa*.

In both these examples the change has taken only a few hundred years. Is it likely then that the changes that occurred after glaciation took any longer? The changes may have been delayed, in places which could be burnt regularly, until the coming of white man but not elsewhere. This idea of delayed succession suggests that the prime cause for succession occurred at the time of the last climatic change. In his study of periglacial activity Davies (personal communication 1962) has shown that solifluction occurred over the entire island above 1800 to 2000' with solifluction "streams" descending as low as 1000'. For the soil to flow it must be bare of trees. This means that all land over 1800 to 2000' has been colonised in the last 6,000 to 11,000 years.

Studies of early secondary succession on mechanically disturbed soils in the Florentine show that, for the dolerite solifluction soils especially, the pioneers are grasses and annual herbs.

One explanation is that Tasmanian man started burning these areas almost as soon as the first vegetation appeared on them and that he didn't stop burning on some of them until white man arrived. The areas that escaped his fires for more than about 10 years soon became colonised by a vegetation that reflected the local rainfall. The areas he burnt regularly supported only _Poa._ Only _Poa_ can support regular fires and still provide feed for game. An alternative explanation by Ellis (1963) suggests that frost prevents the development of _Pteridium_ over 2000' and allows _Poa_ to develop instead of ferns when the rainforest is burnt. Although this did not appear likely in the small part of the Surrey Hills area seen by the author, this explanation allows a much later advent of aboriginal man to the cold highlands.

(c) _Florentine_ On the solifluction and river gravel deposits of the floor of the Florentine the rainfall is between 45 and 50" and here the succession is apparently slower. It is also at a lower elevation, low enough for bracken to take over from the grasses and make the area less attractive for aboriginal burning.

Jackson (1956 - unpublished) and Gilbert (1959) showed fairly conclusively that there was succession in the vegetation on the North Western end of the Lawrence's Creek solifluction area. Gilbert also suggested that the range of vegetations seen in various areas of the valley represented the various stages that would occur on one site if fire could be excluded. However, so far fire hasn't been excluded and although there is no doubt that there is succession in the Lawrence's Creek area, it seems that it ceased elsewhere several thousands of years ago. One contribution to Gilbert's evidence should be made here: in the moderately dense forest where Gilbert described how E. regnans was actively taking over from E. viminalis, there is an amazing lack of downers for so dense a forest. It is conjectured that the succession story here has been roughly as follows:-

About 300 to 400 years ago there was a very open stand of the fire resistant E. viminalis over bracken. To the South East there was (and is) an old, well established fire boundary beyond which occurred E. regnans - Nothofagus mixed forest. The open stand was burnt as usual but then left for an unusually long time without fire. This enabled a fairly dense crop of E. viminalis with a few E. regnans and a shrub understorey to develop sufficiently to have a marked effect on the next fire when it came. This effect consisted chiefly in suppressing the major litter-maker, bracken, shading the forest floor, breaking the wind, and generally weakening the effect of the fire. By this means even the relatively fire susceptible E. regnans survived and were fire-hardened. These trees probably withstood several light fires before the severe 1934 fire. This fire killed most of the E. regnans and a few of the E. viminalis. Both species regenerated profusely, but E. regnans grows much faster and it now had no regular fires to prevent it from quickly dominating the regrowth stand. In only a few more hundred years E. viminalis will probably disappear. Unless aided by man made fuels, the vegetation will no longer support the frequent fires that previously prevented it from attaining its climatic equilibrium.

(d) Judd's Creek Area This area just South of the Derwent - Huon divide was assessed by the author in 1961. There seemed to be a similar succession to that described above. In this case the altitude was over 2500' and the species were _E. gigantea_ taking over from _E. johnstoni_. The reason here appeared to be different and the mechanism certainly was. In this particular area there were very few mature trees standing either alive or dead, but many large fallen dead trees. Fires seem to have swept this area at amazingly regular intervals of 26 to 32 years. Area A was burnt in 1906, in 1934 and in either 1960 or 1961. Area A did not burn in 1914 or 1946 yet adjacent Area B of identical type of forest burnt in these years and did not burn in 1906, 1934 or 1960 and 1961. (Area A represents about 30,000 acres in various large patches, Area B about 20,000 acres). For the vegetation as a whole this is excellent support to the idea of vegetative control of the frequency of fires. However the large dead fallen trees indicated a much better forest than could grow in 30 years. Here the story appears to be one of a fairly sudden increase in fire associated with the opening up of the Moogara and Mt. Lloyd plateaus further North by logging, grazing and berry farming interests about 1900. Annual burning to the North with man prepared fuel has not produced annual fires to the South but it has certainly shortened the period between fires from perhaps 200 years to 30 years.

E. gigantea is more fire resistant than _E. johnstonii_ and it grows faster. This is converting a stable even mixture of the two species to one dominated by _E. gigantea_.

(c) _Catamaran Area_ The Catamaran area was logged in the 1890's and then practically deserted by man. It was assessed by the author in 1962. The fire history here is one of increasing periods between fires. This first big fire after the logging was in 1898, a rather smaller fire burnt Catamaran township and surroundings in 1906. The fire of 1914 reburnt almost all these areas and more recent loggings further North near Leprena and further

South near Cockle Creek. Very little of the regrowth has been burnt since although fires burnt the plains in 1926, 1934 and 1946. The stand probably used to be burnt at intervals of something like 200 to 300 years before man interfered, and since he left the intervals between fires are gradually increasing to this original period after being as low as 8 or 16 years. Where the logging fires trickled into the unlogged forest only enough regrowth was produced to replace the trees that will die over the next 100 or more years.

All the evidence presented for succession so far is restricted to areas where man either began to or ceased interfering with the forest in the last few hundred years.

Evidence Against Succession

The classical English concept of succession does not appear to apply here possibly because of the inevitability of fire. No stable climax vegetation apart from the Man-fern gully type has been found here. It seems that no one species needs the preparation of the site by another before it will appear. This sort of thing may have happened on the great bare areas 6,000 to 12,000 years ago but it is extremely doubtful. Nothofagus, possibly the slowest to invade an area because of it's heavy seed, finds no difficulty in colonising bare mineral soil disturbed by tractors. This occurs under 90% daylight near the Gap.

This type of succession may occur in areas that are burnt only once or twice every thousand or more years. Perhaps as the dense young rainforest becomes old and decadent it eventually becomes sufficiently open to allow the introduction of Huon or King William Pine. However this also is doubtful, at least in the case of the latter which seems to regenerate under its parent stand immediately after fire.

PLATE 20 LACK OF REGENERATION UNDER WET SCLEROPHYLL

This picture shows 35 year old Pomaderris with some Dicksonia. Not only is there no wet sclerophyll regeneration in this stand but there is no evidence of succession to rainforest. This is a fair sample of old wet sclerophyll understorey. Where rainforest species are present under wet sclerophyll they are practically always of the same age and are smaller merely because they grow more slowly.

Gilbert (1959) and Jackson (1961) have both noticed that all tree species that are to inhabit the site are present almost immediately after the regenerating fire. Moreover, Gilbert went on to show that there was only a reduction of species with time, succession by elimination, perhaps better called <u>recession</u>. These findings are entirely opposed to the European and American findings that fire <u>simplifies</u> the tree vegetation. Obviously here it complicates it, while time alone simplifies. This may be in part caused by the generally poor seed dispersal mechanisms found here compared with the excellent wind dispersal mechanisms of the birches, poplars, firs etc. of the Northern Hemisphere. More likely it is due to the almost total lack of species that are dependant on vegetative amelioration of the site before they are able to regenerate. This alone is evidence for the inevitability of fire.

If the extensive wet sclerophyll areas in Westfield and Lords Blocks in the Florentine are examined it must be noticed that there is an amazing paucity of any regeneration of either wet sclerophyll or rainforest understorey species. There is no indication that these areas will succeed to rainforest even if fire were kept out, at least until the present generation of understorey begins to die out. For <u>Pomaderris</u> this is likely to take over 100 years, yet no <u>unburnt</u> stand of eucalypts now has a rainforest understorey 100 years younger than itself. Younger rainforest understoreys are common but only because of fire subsequent to the one which originated the eucalypts. A wet sclerophyll understorey over 100 years old occurs on the Misery Plateau but the only rainforest trees that it now contains are a scattering of <u>Atherosperma</u> of practically the same age.

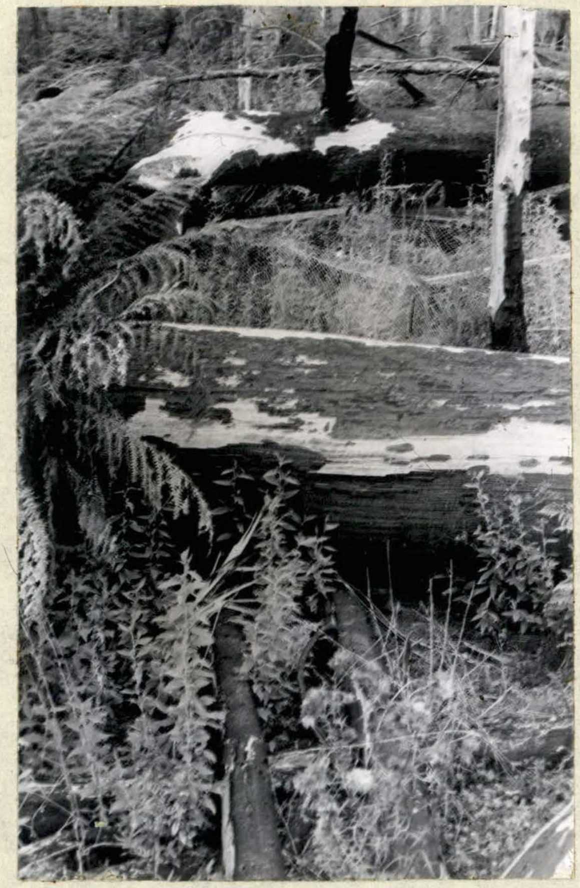
Near the Settlement rain gauge there is an extensive stand of <u>Acacia dealbata</u> and <u>Atherosperma</u> and <u>Olearia</u>

argophylla understorey to an open stand of *E. regnans*. At first sight this seems to present the spectacle of one vegetation succeeding another. If this ~~really~~ is so it is most likely that the wet sclerophyll is winning. This is because the *Atherosperma* instead of being younger, are older than the *A. dealbata*. But succession need not be invoked, all that is required is the appreciation of how quietly a fire must burn under such a fuel-less mixture, hot enough to germinate a few wattle seeds, cool enough to allow some of the *Atherosperma* and all of the *Olearia* to survive. The wattles probably just die of old age. The fires that perpetuated this stand came regularly off the broad limestone outcrop areas to the West.

Although Gilbert showed that there was only a reduction in numbers of species with time since fire, no one area ever contains the entire range in numbers. This means that areas like the parts of the Styx Valley which were unburnt for so long that only four tree species survived, produced only a few new species after the 1934 fire. In this particular case the only addition to the tall shrub and tree layer was *A. dealbata*. Moreover, less than half the fire period will pass before wattle again disappears.

At the other extreme, the most complex wet sclerophyll vegetation found is only joined by a few herbs after fire. Where the fire periodicity is marginal the regeneration is generally most unlike the parent stand. An apparently pure young rainforest can produce regeneration after fire that contains *Pomaderris*, *Phebalium*, *Zieria*, *Coprosma*, *A. dealbata*, *A. melanoxylon* and a few other wet sclerophyll species. Most of these come from ground-stored seed. ~~and~~ In past fires relatively few of these seeds would germinate and all would have to compete with dense fern shade in their early life. The result would be conditions that would give

Plate 21 SUCCESSION CAUSED BY LOGGING AND BURNING



This picture shows the good pomaderris regeneration occurring on a site that previously carried an understorey dominated by Nothofagus.

The effect is produced only on certain types of rainforest which have had a high proportion of wet sclerophyll in the mixture that regenerated after the previous fire. The wet sclerophyll plants have for the most part died out but the stock of ground stored seed ensures its reappearance after the next fire.

When this next fire occurs after logging and after the felling of the rainforest seed trees the pomaderris regeneration has no rainforest shade, no rainforest seed, little "wet fern". In other words there is a definite succession from rainforest to wet sclerophyll understorey.

It is quite false to reverse two observations in time and conclude that dense pomaderris regeneration becomes Nothofagus rainforest understorey in 100 years.

the rainforest species at least an equal chance of competing with them so that only a few of them would survive to produce seed for the new ground-store for the next fire.

It is in these marginal stands that logging and understorey felling and burning tend to create the most misleading evidence :-

Under these conditions it is common to find a sea of wet sclerophyll regeneration with no rainforest regeneration where a practically pure rainforest understorey used to stand. The observer so often tends to reverse the two observations in time and he concludes that dense wet sclerophyll regeneration is in 120 years converted to pure rainforest understorey. This is ~~quite~~ untrue. The dense wet sclerophyll regeneration now present is the product of conditions ~~completely~~ foreign to those following past fires. The extremely hot fire has destroyed both the shade and the seed of the rainforest, it has prevented wet fern becoming established and removed it where it was already established, and above all it has germinated many times the number of ground stored seed that any natural fire could do. The dense wet sclerophyll understorey regeneration will take many generations of natural fire to revert to rainforest understorey. Burning the almost pure rainforest understorey does not produce this sort of regeneration by natural means. (Where old rainforest understorey was burnt in 1934 <u>No</u> <u>Pomaderris</u> regenerated).

<u>Evidence of Fire Cycles</u>

The evidence required to prove the existence of a fire cycle would be proof that any one site now carries a vegetation that corresponds almost exactly to the vegetation that it carried at the same stage of the previous cycle. This is not easy to prove. The most obvious evidence is the simple species list. Rarely is it possible to trace the stand history more than one or two fires back. The distributions of the species in past stands can only be guessed.

(a) Treeless Areas in the Wet Climates Over much of Western and Southern Tasmania treeless areas occur. The lack of trees appears to be due chiefly to a very high winter water-table. These areas grow a dense low dry sclerophyll vegetation which can be burnt at three to four year intervals. If left unburnt for longer than four years fuel just goes on accumulating until a suitable spark arrives. These treeless areas form the major "fire highways" through the much less inflammable forest.

Near these treeless areas where drainage improves, trees grow. At first short peppermints with a similar dry sclerophyll understorey; then the ash eucalypts with a wet sclerophyll understorey; then the ashes with a rainforest understorey; then pure rainforest.

The ages of the eucalypts near the treeless areas generally increase as the distance from these clearings increases. This could be interpreted as indicating that the forest is encroaching on the clearings due perhaps to less frequent burning since the aborigine disappeared. A possible increase in rainfall could be used to explain why the less frequent fires should burn less country.

However I do not feel that this evidence indicates a succession from treeless area to forest but rather a relatively stable relationship between the various vegetation types and their environment which includes fire. The argument detailed below discusses how past fires could have started and suggests why they went out where they did.

If it is accepted that the vegetation and the pattern of fuel development influence the fires neither aborigines, nor increased rainfall need to be blamed.

The phenomenon of frequent spot fires has been proved by the evidence from S.18. (See later) Spot fires, combined with lightning are sufficient to explain the burning of some of the treeless areas without help from the aborigine.

It is absolutely inconceivable that aborigines lit every treeless area every time it burnt. It is known that the aborigine lived on the coast and in the drier parts of the Midlands and the Derwent Valley. Where he crossed from the N.W. coast to the coastal plains of the West Coast he made a track. If the aborigine had been able to wander freely over the entire island he would have had no need of tracks. Yet he made at least this one track which he used every year. This track goes through the denser vegetation types to be found on the island but the same types are just as dense elsewhere.

The only reasonable conclusion we can draw is that the aborigine was in the dense country very rarely except to pass from one area of open country to another, and that this movement occurred in a very few areas.

No convict or gang of convicts escaped from Macquarie Harbour to the East even when they took their food "on the hoof" so to speak by turning cannibal.

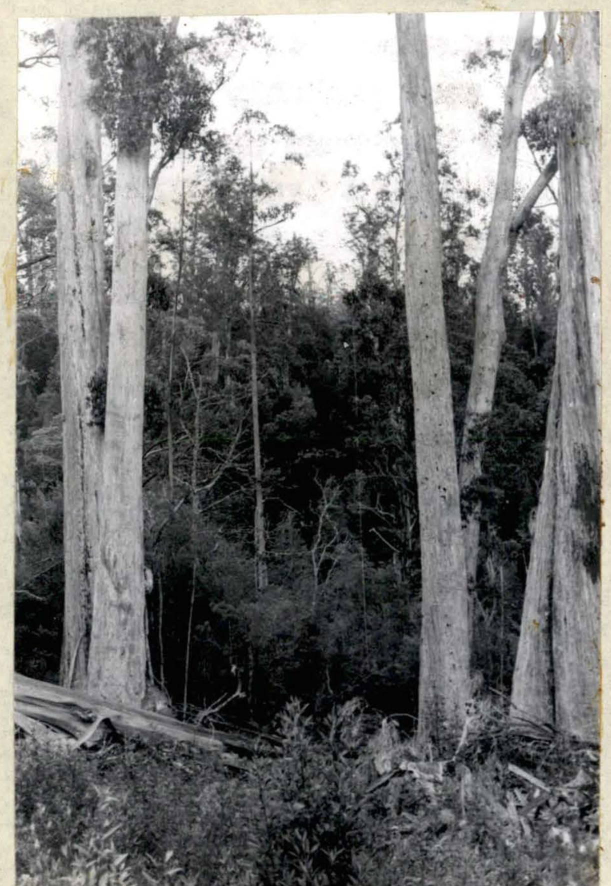
There was very little inducement to the aborigine to penetrate the dense forest. Not only were there far fewer animals but his staple diet, the larger marsupials, were practically absent.

The sum of all these unfavourable conditions must be that man was never a regular traveller or burner of most of the treeless areas found throughout the wet forest. However, he certainly burnt the open forest to the East, the more continuous coastal plains to the West and some highland Poa grass areas in the N.E. & N.W. He no doubt ventured far onto other wet forest sites for a few years after the major periodic fires in much the same way as snarers do today. But it is considered extremely unlikely that either hunters or hunted continued to do so for many years because of the deterioration of access for either with time.

If local aboriginal burning and change in climate are rejected, what other explanation is there? Surely ~~only~~ that of site induced differences of fire susceptibility. The plains obviously burn most often of all types of vegetation in the wet areas, the rainforest obviously burns least often. Both have well marked topographical or drainage sites. Surely the intermediate sites should have intermediate qualities including those of fire susceptibility and fire frequency? If this is accepted all that is now required is the inevitibility of fairly regular fire over the last 6000 years over the whole island.

That fires have occurred somewhere on the island over the whole period is evidenced by the wide distribution of the Eucalypts; moreover, they must have done so at less than 500 year intervals for the same reason. The wet sclerophyll understorey where it occurs now must have been burnt at not more than one hundred year intervals for several generations. It appears to be unable to regenerate without fire. There must have been fires at <100yr. intervals in some parts of the island for five thousand years to have this vegetation at all. These parts could have been on the move for the period but as they appear quite stable now unless disturbed by man, it is reasonable to assume that they have been so for most of the last 6000 years.

Plate 22   THE S.18 WET SCLEROPHYLL PATCH



This is a small area of E.obliqua, E.regnans forest with a wet sclerophyll understorey in a sea of E.regnans forest with a rain forest understorey.

This patch has been burnt at least once every 50 years while the surrounding forest has not been burnt for 350 years.

The presence of the stringy barked E.obliqua probably accounts for the local conversion of sparks into spot fires. However the fact that these fires were regularly limited to the same area can only be attributed to well defined differences in the pattern of fuel accumulation.

If the location of the wet sclerophyll understorey has been stable for so long, only regular fires have kept it so.

(b) Islands of Eucalypts in the Rainforest

This is part of Jackson's evidence. He showed quite clearly that these "islands" were most probably remnants of a once continuous cover, but he then went on to suggest that because they are now surrounded by a less inflammable vegetation than their own, fire would reach them less often and that some would escape fire long enough for the eucalypts to die out and be replaced by pure rainforest. But where replacement of this sort is definitely occurring today, it is extremely rapid. Any of the islands which were going to disappear probably did so at least 4000 to 5000 years ago. Where these islands have Eucalypts younger than the surrounding rainforest they must have been burnt more recently. If this is so they probably burn more often. If these islands are the same age as the rainforest there must have been a mechanism which prevented them from enlarging at the expense of the rainforest and kept them "islands" for a considerable time. The same reasoning applies if there are Eucalypts on the island older than the rainforest.

Two examples, one from the Styx, the other from the Florentine, illustrate these two types perfectly:-

Styx - S.18 On this coupe there is a small patch of unusual forest. Unusual in that it has a wet sclerophyll understorey and multiple ages of E. regnans and some E. obliqua as the overstorey. It is surrounded by the usual Styx old mixed forest for a mile or more on all sides, including more than two miles to the North, North-West and West. This stand is on an outcrop of conglomerate, plus some particularly hard siltstone. There is absolutely no doubt that the stand has been burnt by every major fire for at least the last several hundred years, probably the last several thousand years. There is equally no doubt that the mixed forest that surrounds it has <u>not</u> been burnt for 250 to 350 years. As previously stated, this patch cannot have received the only spark from a dozen fires which by chance alone failed to burn the surrounding old mixed forest. Moreover, it was not chance that put the fire out in the same place each time. The only possible explanation for the "island" is that of vegetation-dictated fire susceptibility and frequency. The same explanation is by far the best one to account for all the other "islands" even if they only differ from their surroundings in that they carry a few old Eucalypts.

In the S.18 example, the difference in the vegetation is obviously due to the unusual site. But all these Western Tasmanian "islands" are not merely "islands" of different vegetation, they are topographical features which must have at least better drainage than their surroundings and therefore have different sites.

It is therefore considered that the following interactions of site, vegetation, fire frequence, and fire susceptibility has determined the vegetative cycle for any particular site:-

1. <u>Under a given climate the one site produced a certain vegetation</u>.
2. <u>This vegetation became fire susceptible and burnt a reasonably constant time after its originating fire and so regenerated itself in entirety</u>.

These hypotheses lean on the assumption of a relatively constant climate over the last 6000 years. They describe only those areas that have not been prevented by man from attaining their equilibrium with the climate. Fires, at least the periodic great fires, are considered an inevitable product of the vegetation and the climate in which man's part in their initiation was, in the past, constant.

PLATE 23 AN "ISLAND OF EUCALYPTS IN A SEA OF RAINFOREST"

This is one of the smallest "islands" seen. The picture shows K. Cremer standing under a tight little group of E.regnans all growing within a circle of 20' radius.

The trees in the group are of several ages, each regenerated by fire. The surrounding rainforest is of at least two ages as it contains a high proportion of trees that survived the last fire. There appears to be no indication that either vegetation advanced at the expense of the other between or immediately after fire.

Because of the qualifications listed above, it is likely that the hypotheses are generally sound only in those areas with over 50" annual rainfall, plus areas with 40 to 50" which were not bared by the last glaciation.

A further important qualification is this - although the vegetation appears to burn regularly, it is only very rarely that the entire previous generation is destroyed. This is especially marked in the case of the more fire resistant Eucalypts although individuals of both _Atherosperma_ and _Nothofagus_ have been seen to survive many fires, while _Olearia argophylla_, in some places, seems almost indestructible. Other species may survive until the regeneration fire in the form of ground-stored seed.

Florentine - Road 4 Area In this area there was, until logged, an extensive stand of young rainforest. In this stand there were numerous stems of dead _Acacia dealbata_ lying on the ground or leaning against vigorous rainforest trees of the same age. One of these wattles is still alive and can be seen every August and September, when in flower, from the Tim Shea quarry. Also, in this stand are a few curious little clumps of _E. regnans_ of several ages.

The first impression is one of succession from wet sclerophyll to rainforest. However, although there were certainly many wattles in the stand they are now surrounded by rainforest trees which from their intensely clumped distribution obviously originated from coppice. This means that both wattle and rainforest co-habited this site last time - so why not the last/50 times?

The tiny groups of Eucalypts are particularly interesting. The smallest group consisted of several trees growing entirely under the crown of one big tree. The trees were of several ages. The youngest was the age of the younger rainforest trees (some rainforest trees survived the last fire undamaged). This means that for the last few fires the Eucalypt had been unable to extend outside its original crown cover. The explanation for this is most likely found in the way the fire burned. It obviously wasn't very hot as far as the rainforest was concerned. There was probably far too little fuel. When it reached the heap of bark and branches that always collects under lone Eucalypts in the rainforest, it developed into a local bonfire. The light fire under the rainforest encouraged a rapid cover of wet fern which only the toughest survivors of the ground-stored wattles succeeded in piercing. The bonfire killed all the underground rhizomes of the wet fern allowing some Eucalypts to become established. The better lighting near the fire-damaged Eucalypt ensured that some survived.

In both examples, the story is of different vegetations having different burning qualities in either degree or time or both, but it can only be assumed that the tiny Eucalypt clump must, in fact, be a tiny different site today. However, it is quite possible that it originated by chance in this case. Wherever the clumps are of any size it is fairly easy to account for their survival since the last ice age in terms of topography, geology or drainage.

(c) Fuel Development. To burn repeatedly there must be a repeated build-up of fuel. MacArthur (1962) has shown that to limit accumulation of litter in dry sclerophyll forests burns should be made every 5 years or so. He also says that if left longer, the litter continues to accumulate and endangers the stand. He extended this experience to all types of forest on the assumption that there too the litter builds up quickly. This is obviously untrue in the case of the other extreme - rainforest, and takes little to disprove in most wet sclerophyll vegetations. If wet sclerophyll forests are burned at very short intervals the fire tends to burn patchily and go out through lack of fuel. Whereas the dry sclerophyll vegetation contains a large quantity of inflammable materials, even when green, and rots very slowly when dead, rainforest and wet sclerophyll vegetations are characterised by relatively rapid rates of litter decay.

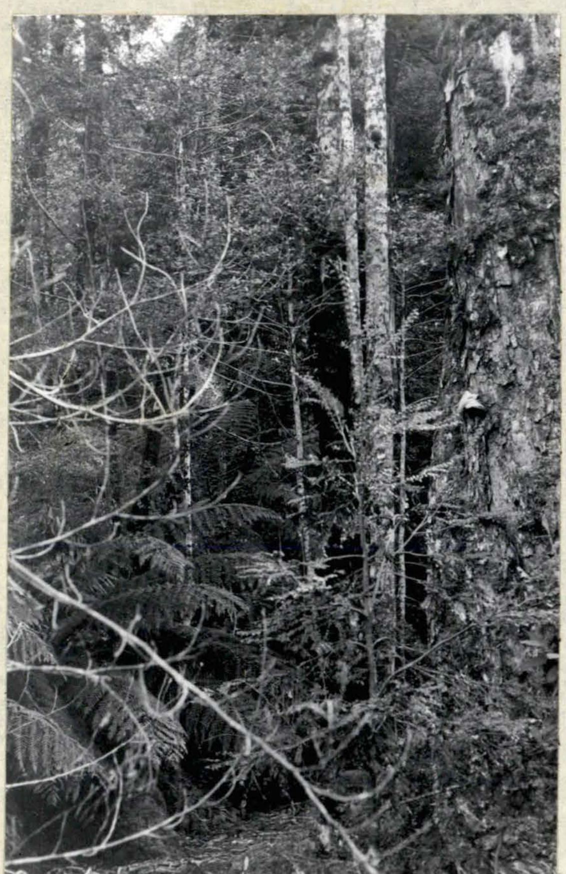
In mixtures of Eucalypts with wet sclerophyll or with rainforest understoreys, the Eucalypt litter accumulates much more rapidly than that of its understorey. This is hardly surprising as the Eucalypts exhibit most of the other characteristics of dry sclerophyll vegetation. One surprising feature of the rainforest understorey is that Nothofagus, Atherosperma and Phyllocladus all bear leaves which are relatively more inflammable than the leaves of the typical wet sclerophyll understorey species. This greater inflammability is probably counter-balanced by a combination of a higher rate of decay with the fact that the rainforest species occur on sites which dry out for shorter periods each summer than those sites carrying wet sclerophyll species.

It is considered that, with the aid of an average stocking of Eucalypts typical to each vegetation, it would perhaps be possible to produce a burn for the control of litter at 10 year intervals in wet sclerophyll understorey and at 50-100 year intervals in a rainforest understorey. Even then, in both cases, it would probably end up as a bonfire at the base of each Eucalypt with a harmless creeping fire in between.

The most important example of this question of fuel development is the way that young rainforest acted as the only natural fire break in 1934, yet old rainforest, with 200 or more year's accumulation of fuel, burnt most successfully (See Fire Behaviour Section).

The range of ages found around the treeless areas in the wet country are probably just a product of different rates of fuel accumulation. Each rate controlled by the vegetation, each vegetation controlled by the different sites,

Plate 24 MAINTAINING THE EQUILIBRIUM



Two views of the same Nothofagus seedling. On one side is growing 250 year old rainforest understorey, on the other 1934 Pomaderris killed by the 1959 fire.

This remarkedly sharp vegetation barrier has apparently been maintained by a narrow trench 2' deep on an otherwise level surface.

This feature appears to have stopped 5 or more fires since the rainforest last burnt. It certainly shows that all fires in the Pomaderris in the last 250 years have been creeping ground fires.

all under one climate in space and (6,000 years of) time.

Proximity to Fire Source

Supposing that it is accepted that similar sites have similar periods of fuel scarcity and become susceptible to fire at similar ages, what is the effect of such factors of proximity to fire source or topographical protection from a nearby fire source? It is likely that the distant site will receive fewer sparks than the near one and that the protected site will be threatened by fewer ground fires than the unprotected.

This problem is not relevant to the argument if it is also accepted that the vegetation is a measure of the site. On button-grass sites fires have occurred often enough to maintain the button-grass whether it exists as an extensive plain or as an isolated patch surrounded by seldom burnt forest. If it is still here several thousand years after the last major climatic change there is no point in speculating how the fire got there - the presence of the button-grass is sufficient evidence to say that it did. Often two such sites are not so similar when the species other than button-grass are examined and their respective fire frequencies are likely to be relatively very different. However for button-grass to be present both sites must have burnt at intervals short enough to prevent the site being taken over by other species. Sites and vegetations that carry fire infrequently are most likely to burn only in bad fire years after they have accumulated enough fuel. I believe that in such years the effect of the spot fire mechanism can encompass all similar sites several miles ahead of the fire source. As the species composition of these older vegetations remains nearly constant over very long periods any areas not burnt by one fire because they were not showered with sparks will be available to burn some time in the next 100 or so years when sparks or lightning do arrive. (See page 44 - 1934 Fire in the STYX VALLEY)

Proximity to the fire source is in fact just another factor of the environment, a quality of the site. After the last climatic change it may have had a profound effect in determining site differences. Too frequent fire may have prevented the invasion of fire susceptible species. If this was the case the vegetative changes would have occurred in a very few generations. It is considered most unlikely that there is still succession occurring due to the chance that fire will not come to a particular site soon enough to preserve its present species composition (c.f. Jackson 1956) On the contrary it is considered that sparks arrive several times in the lifetime of the older vegetations but these sparks only turn to fire when the fuel has sufficiently accumulated to carry the fire.

The aerial photographs in Plate 1 shows the southern end of the Tiger Range and the marked difference between the vegetation on the two aspects. In this area the fire source has been the Gordon Plains and these fires have swept up the western slopes of the range and gone out at the ridge-top. The interesting point is that the patches of forest on the western slopes have aspects, slopes and parent materials which are for the most part identical to those of the frequently burnt areas, which carry no forest. However each patch of forest has a minor ridge down slope. The effect of this ridge is somewhat complicated; if it was just one of fire protection the presence of eucalypts in the patch is hard to account for. It is possible that there occurred a period without fire that removed some of the more inflammable species and allowed sufficient humus soil to accumulate to carry tall trees and that the vegetation that developed as a consequence has fire frequency of its own. A more likely explanation is connected with insolation and shade.

Immediately east of the minor ridge the site supports the same tall forest as the eastern slopes of the range. It is believed that the shade from this tall forest has had a marked effect on the western slopes immediately above the ridge and allowed tall forest to develop which in turn has shaded more of the western slope. In effect it is considered that where the forest grows on the western slopes has been a different site for a very long time.

Whatever the explanation for these forested patches they are certainly now different sites to the tree-less slopes and have developed different site qualities one of which is fire frequency.

When vegetations are discussed in a broad sense they are commonly divided into a few groups such as "Button-grass plains", "rainforest", "mixed forest", "wet sclerophyll forest" and so on. Within these broad classes it is quite obvious that there will be almost as great a range in fire frequencies as between the classes. However if the vegetations are subdivided more carefully in terms of the species present it is believed that a small range of fire frequency would cover each subdivision. This general idea may not apply when old mixed forest or rainforest is burnt and the site is taken over by <u>Pteridium</u> (See page 81 - "Two Sorts of Fire Cycles?")

<u>Maintaining the Equilibrium</u>

If there is stability between the vegetations it should be most obvious at the boundary between them. If one vegetation is suceeding the other in time it must also do so in space. Examples have already been discussed where the boundary has been stationary for the last several fires. But in all these examples the vegetation could, to a great degree, control the way the fire burned. Islands of Eucalypts carry a fire that has to both go down hill and burn less fuel if it is to spread. Fires from treeless areas meet with more and more wind resistance as well as decreasing fuel. Both fires have little chance of spreading far until the supply of fuel is built up to a critical point.

What happens along the long Eastern and Northern borders between the major areas of Tasmania's rainforests and her wet sclerophyll forests?

Examples of this ecotone occur in all three of the valleys studied.

What happens when a hot fire in the wet sclerophyll understorey hits the rainforest understorey, or even pure rainforest?

To this question there appears to be more than one answer depending on the age of the rainforest and to some extent the density of the overstorey.

(a) <u>The 1934 Fire in the Florentine Valley</u>

The fire probably started from sparks coming from the rim of the Rasselas Valley to the West where some tall <u>E.gigantea</u> were burning. (This is not entirely supposition, exactly the same effect occurred two or three years ago when the same stands were again partly burnt, fortunately this time there were no live sparks only much ash and charred leaves. Moreover, in 1934 the local conflagration is reported to have started in the Rasselas Valley).

The live sparks probably started fires at the settlement and on the tiny remnant savannah plains at the end of the dolerite solifluction sheet. The fire spread rapidly and almost certainly burned as an understorey crown fire in the wet sclerophyll stand on Lawrence's Creek gravel at W.10 quarry. Here an enormous area of _E. regnans_ was fire killed. But the stand immediately to the North, on a slightly higher level, suffered little damage and now contains relatively little 1934 regrowth. This is a first-class example of the hotter fire occurring where the winter water table was nearer the surface. Even immediately to the South of this stand where the site changes from dolerite gravels to dolerite solifluction again most of the trees survived.

From here South the vegetation gradually began to control the fire chiefly by offering less inflammable fuel and by reducing the wind speed at ground level. Only on the poor quartzite ridges did the fire burn freely down towards the start of the ridge-top rainforest South of Road 10. This rainforest was characterised by _Phyllocladus_ with some _Nothofagus_ and an overstorey of _E. gigantea_, _E. salicifolia_ and _E. obliqua_. The fire spotted down this ridge to it's end at Road 9 and as a final effort spotted across to the Southern-most spur of this road system and then died down. It had finished its run. Unfortunately, next to the ridge carrying the poor rainforest type there was a stand of old mixed forest consisting of a few _E. regnans_ over fairly dense _Atherosperma_ with some _Nothofagus_. The ridge top had a well developed humus layer because of its site and the vegetation that this site produced, and the older mixed forest also had a reasonable accumulation of humus due chiefly to its age.

The fire spread slowly Westwards through this layer and when it reached younger mixed forest it went out. It also spread Southwards until it had to travel down hill into a system of small gullies where it again went out.

Another branch of the fire burned from the gravel flats of the Lawrence's Creek Valley right through to the Park boundary. It left the bed of the creek where the gravel flats peter out and ran along the Southern bank of the creek. Just West and South of Lawrence's Creek bridge it burned a broad stand of E. regnans, E. gigantea, Nothofagus mixed forest in which the Eucalypts were about 100, 180, 250 or 350 years old and the rainforest was 100 years old.

The regeneration following the two fires was markedly different. Where young rainforest burned on a drier dolerite site consisting chiefly of Nothofagus, the regeneration was that of the Eucalypts plus Nothofagus, plus Pomaderris. The densest Pomaderris occurred where the fire had been hottest but always with sufficient Nothofagus to become rainforest again with the passage of time. Where the fire was lightest a few of the Nothofagus survived over wet ferns and manfern. Where the fire was average the Nothofagus regeneration equalled or exceeded the Pomaderris in both numbers and growth rate. This fire seems to indicate that the vegetation either regenerated itself or it might possibly have been slightly shifted towards wet sclerophyll. (Some of the Pear patches were exceedingly dense).

The fire in the old mixed forest didn't regenerate mixed forest. Only a few rainforest trees recovered by means of coppice, only very patchy Eucalypt regeneration occurred. Both indicate that the fire was relatively cool, it killed insufficient wet fern for dense Eucalypt or rainforest regeneration but it allowed a few of both rainforest species to regenerate or survive.

As the many dead rainforest trees began to fall over the area became too exposed for wet fern and this was replaced by bracken. After a further few years most of the area burnt again in October 1950.

On neither occasion did any wet sclerophyll understorey regenerate but for a few A.dealbata after the first fire. Little else but bracken regenerated after the second fire. The area burnt again in 1961, killing several of the 1934 regrowth trees. However, this time they had seed on them and if the stand had not been disturbed by man the slow expansion of the eucalypts would have proceeded a further stage.

Although both of the fires subsequent to the 1934 fire were started in unnatural conditions the fuel was there, and this could have happened quite easily by lightning or spot-overs from other fires if they had been around. Without white man's preparation of fuel in the adjoining forests, and without his matches, there would have been much better odds against this bracken burning so soon, but it would have lit at the first spark over a period of 30 years of more.

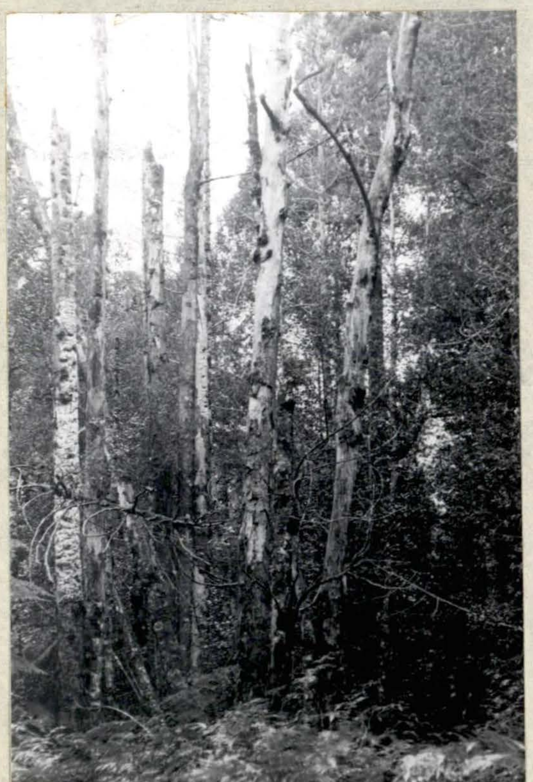
(b) Fires in Rainforest.

It should be noticed that the two examples of rainforest which burnt at a young age were either nearly pure Nothofagus, or a Nothofagus - Phyllocladus mixture with the latter common on acid sites. The reason that either burnt was because they built up sufficient fuel to carry a strong ground fire in only 100 years. It has already been suggested that young rainforest is practically unburnable and if this is to remain true it requires some qualification. The common type of rainforest in this area is an intimate mixture of Nothofagus and Atherosperma. This sort of understorey or pure rainforest appears to be able to resist fire for 150 years or more. The mechanism seems to be one of rapid decomposition of the mixed litters of the two principal species. Where only Nothofagus grows a layer of fine twigs accumulates up to a foot deep in places. Where Nothofagus grows with Phyllocladus there is a strong development of unincorporated humus as well as this twig layer. Both are sufficient to carry fire from about 90 years onwards.

What happens where pure Atherosperma grows? Atherosperma has a very rapid litter decomposition rate. This mechanism enables individual trees to survive successive ground fires in some wet sclerophyll stands. The oldest Atherosperma found were 250 and 270 years old but most trees seem to die long before this. If young or old rainforest is inspected there can generally be found a progressive distribution of size classes (see Gilbert 1959) but in many cases this is not a progressive distribution of age classes. In pure stands the smaller stems are mostly coppice and are generally very close in age to the larger stems. Few seedlings occur. As the stand grows old individuals die-back to ground level and often die altogether. The dead trunks are fuel in the air for only a few years before they fall over to become fuel on the ground. After about 100 years the stand begins to open out and the wet ferns form a dense ground layer and litter begins to accumulate. This continues until the stand is burnt by spot fire or ground fire. If the fire occurs early in the stands recession it is light and all the existing stems coppice strongly whether fire killed or not and so the stand

Plate 25   THE PURE ATHEROSPERMA STAND - STYX VALLEY

(a) The last Nothofagus in the stand is here seen dead after the 1960-61 drought. In the same year one of the two last Ac.dealbata toppled over and died.



(b) Decadence and death of the Atherosperma growing in a pure stand. These trees are probably of coppice or seedling origin following fire about 100 years ago. It seems that the first spark in a dry year will cause a fire in the sort of fuel, and that this fire will regenerate the Ac.dealbata-Atherosperma mixture.

is regenerated. If it happens late in the recession there may have to be a bracken waste period followed by recolonisation via the manferns.

The above hypothesis is considered the best fit of the peculiar evidence found in the pure _Atherosperma_ stand in the Styx Valley. In this stand are occasional _A. dealbata_ flourishing over the _Atherosperma_ along with dead and dying _Nothofagus_. Examination of the quarry nearby suggests that the _Nothofagus_ died of drought. (The last tree, the largest one, died in the drought year 1960-61). The stand occurred on extremely shallow soils over rocky mudstone. The _A. dealbata_ shows the stand was burnt about 100 years ago. The extremely clumped distribution of the small _Atherosperma_ stems suggests that they have originated from coppice. And, last of all, the stand is deteriorating extremely rapidly on the exposed edge of the road and in spots away from the road, and will in a very few years be ready for its regenerating fire.

The oldest stand of rainforest in the three valleys was burnt by spot and creeping ground fire in 1961. This stand was a mixture over 450 years old dominated by _Nothofagus_ but in numbers had more _Atherosperma_. Even after 450 years the _Nothofagus_ showed no progressive distribution of size classes. Even so it is considered that if such a forest does occur where fires are nearly unknown this particularly high quality stand might be able to regenerate itself when the giants fell over. However, fire has been ever present, at least with a frequency of under 1000 years. Even if the big _Nothofagus_ did just fall the stand would be for many years dominated by decadent _Atherosperma_. The longevity of the stands appears to be connected with the development of aerial moss. It seems to be less abundant here than in the younger "old mixed forests" of the Styx. This moss is one of the prime sources of spot ignition.

(e) Recovery from Bracken Wastes.

The 1934 fire produced extensive bracken areas in both the Styx and Florentine Valleys. Some of these areas are still unforested thirty years after the fire. This is fairly easily accounted for in the Florentine by the 1950 and 1961 fires but in parts of the Styx Valley there are big areas of bracken not burnt for 30 years.

That these bracken wastes do eventually return to forest can be seen near the junction of Lawrence Creek and the Florentine River and in Andromeda Block in the Styx Valley. In both places the majority of the understorey trees are Atherosperma which have regenerated on Dicksonia stems. It is presumed that the areas were once bracken covered with no seedbed available on the ground. Atherosperma seeds drifted onto the Dicksonia stems, took root and eventually shaded out the bracken. (See pages 33, 34 and Plate 16)

Two Sorts of Fire Cycles?

It appears that the hypothesis of Fire Cycles may require enlarging to cater for the ecological position of Pteridium. The Lawrence Creek branch of the 1934 fire regenerated the stand it burnt. In other places it produced bracken. The one thing common to the bracken areas appears to be a high level of humus fuel before the fire. It is possible that if this humus fuel is not burnt away in one fire, bracken regeneration is favoured to such an extent that further fires are likely because of the rapid production of bracken fuel. By the time the site is re-colonised via Eucalypt shade or Dicksonia the heavy fuel accumulation is likely to be markedly reduced. It may be that this is nature's way of removing the debris of several hundred years of forest growth and preparing the site for the next generation of forest.

Perhaps short cycle vegetations burn one and are regenerated while long cycle vegetations may pass through a period of many fires before regenerating.

The high density forests of the middle Florentine Valley may be the product of repeated light burning under relatively few old trees of the previous stand. The ignition of these fires was quite possibly, but not necessarily, by aborigines. But the fact they burned less and less well suggests that they were meeting greater and greater resistance from the vegetation. Even with the advent of the Dawson's Road only rare man-made fires escaped the actual cleared area of "The Settlement". This can be interpreted as succession evidence but it is just as easily explained as a later stage of the recovery from bracken under a reasonable cover of Eucalypts.

Summary of Conclusions - Part IC

1. Ecological equilibrium, if it exists, must be dynamic.

2. Of all the factors of the environment only one has markedly changed since the end of the last glaciation over 5,000 years ago. This factor is man. The change occurred with the coming of white man and the destruction of the Tasmanian Aborigine. The change was principally from broadcast burning of the open lands to more purposeful exploitation and clearing and burning of the denser forest. However, in some places the change brought decreased burning, at least for a few years.

3. Succession is now ocurring where the pattern of burning and fuel production has changed in the last 150 years. Succession is believed to be limited to these areas.

4. The dense forest was seldom visited by the Aborigine.

5. Dense forests existing at the time of the coming of white man remained in a state of dynamic ecological equilibrium until disturbed by him. The disturbance was generally accomplished by the preparation of unnatural quantities of fuel and by the change in fire behaviour this caused.

6. Ecological equilibrium consists of repeated regeneration of the same vegetation on any one site. Regeneration occurs only after fire except for a few individuals of a very few species.

7. Fires in these areas have occurred sufficiently regularly over the last 5,000 years to prevent the species now present from dying out between fires, but not too often to destroy them.

8. Lightning and spot fires have been the ever present fire sources. These together have ensured that no site remained too long without fire.

9. The fuel produced by the vegetation determines the success of fires that occur and prevents fires spreading too often to any one site.

10. The vegetation that develops on the sites of optium moisture and drainage burn least often. Moreover this vegetation accumulates the least fuel of all vegetations and so re-inforces the fire resistance of the site.

11. Conversely, the vegetations that develop on the sites of worst drainage or fertility burn most often. They aggravate the siteb tendency to dry out every summer by producing highly inflammable fuels both as live and dead material. They appear to have developed the ability to ensure fire destroys and regenerates them at fairly regular intervals. They are pre-disposed towards fire. This pre-disposition towards fire occurs in these vegetations within a few years of their regeneration while the plants are still actively increasing. For the vegetation on thebest sites this pre-disposition, if it can be so called, only occurs with decadence and death.

12. The two extremes described have a whole range of intermediate sites between them. The intermediate sites produce intermediate vegetations which have intermediate fire characteristics.

13. This association of vegetation, site and fire frequency is the most reasonable explanation for the phenomena of "islands of eucalypts in the rainforest". These "islands" are not necessarily fast disappearing remnants of a once complete eucalypt cover. They are stable types perpetuated by their peculiar site and lightning, spot or ground fire.

14. The increase in age of vegetation with distance from the plains in the dense forest is best explained by differences in site and fire frequency. It is most unlikely that they are the product of two immeasurable factors - climatic change and decreased aboriginal burning.

15. The fire frequency of each site is to a very large extent determined by the rate of fuel accumulation. This in turn is determined by the rate of fuel production and the rate of fuel decomposition. The most efficient fuel disposal seems to occur under pure Atherosperma stands. However, these pure stands are not particularly long-lived. The best long term disposal seems to require an intimate mixture of Nothofagus and Atherosperma.

16. Proximity to fire source may have once had a profound effect on the site but if the vegetation now present is an acceptable measure of the site, the distance from a fire source to two similar sites cannot be expected to alter one site now when it could have done so any time in the several thousand years since the last climatic change.

17. The classical concept of succession, one of change, and increase in species with time since disturbance, does not appear to be of importance here. Here is only recession, at least in the number of species.

18. No regeneration occurs under old wet sclerophyll stands. Fire appears to be the only regenerator. This vegetation appears to have developed a pre-disposition to fire intermediate to that of the dry sclerophyll vegetation and the rainforest vegetation.

19. Without mans interference, fire adds only a few new species to the vegetation. These new species are either ephemeral herbs or ferns of wind blown origin, or they are the product of the dormant part of the vegetation - the ground stored seed of its shorter lived members.

20. Pomaderris and Nothofagus and A.dealbata and Atherosperma represent two mixtures of the two major vegetations that are stabilised on some sites that have a fire frequency of about 100 years. At the start of each "rotation" the wet sclerophyll species appears to control the site, at the end the rainforest species do. The well known pure Atherosperma stand

in Gold Creek Block is not a climax vegetation. It appears to be a short cycle vegetation on a site which is extremely efficient in removing Nothofagus by drought and A.dealbata by time.

21. After an extremely long period of fuel accumulation before fire there may be an ecological pause represented by Pteridium and a period of many fires. This pause is only overcome by shade and the peculiar properties of Dicksonia. After shorter periods without fire the vegetation may be regenerated by one fire.

PART I.D. UTILISATION OF THE FOREST

Logging Practices and their Effect on the Forest

Most past Tasmanian sawmilling operations had little other effect on the succession than to increase the fire frequency by increasing the fire susceptibility. In some areas this has resulted in producing sufficient regeneration, in others, where the frequency was too high, it has resulted in bracken wastes with a few scattered trees.

Relatively little mixed forest was logged in the Maydena area until about 1950 and less was logged but not burnt. Eucalypts were known to regenerate to some degree after logging all other forest types and it was assumed that they would also regenerate in logged, unburnt rain-forest understorey if left long enough.

Before 1950, logging in this area was limited to the Lower Styx working and the Tyenna Valley. Regeneration occurred on most wet sclerophyll areas and slash burns or the 1950-51 wild fire regenerated most of the mixed forest logged. The standard of utilisation, although much higher for pulpwood than for sawlogs, still allowed a considerable number of cull seed trees to be left on most areas.

Since 1950 the utilisation standards have increased and large areas of mixed forest have been logged. Fire protection has been very good here and until 1959 all slash burning was done fairly late in the season or else in spring and with no preparation of fuel.

All these factors led to large cut-over areas having few seed trees, much live rainforest understorey and heavily compacted tracks. These areas produced very little regeneration. Even the slash burnt areas were only 50% or less successful due to poor distribution of seed trees, burning in Spring and other factors.

The effect of modern logging practice on the forest succession is enormous. High leading operations flatten the vegetation and ensure a very hot burn. Removal of the eucalypts and their seed gives species with ground stored seed an advantage over the eucalypt regeneration. Slash burns on relatively small areas of mixed forest sometimes produce nothing but the "wet ferns" because of lack of seed combined with intensive browsing. In such cases neither forest type is regenerated and the area may revert to pure Pteridium. Good slash burns, particularly after slash felling, must be very much hotter than any natural fire.

Volume Control.

Very extensive assessments of mature forest by the strip method were carried out by A.N.M. (~~[illegible]~~) during 1947 and 1948 in the Florentine, Broad, Repulse and Junee areas.

More intensive assessments of mature forest were made from 1955 onwards by both A.N.M. and Forestry Commission teams.

Detailed volume information was kept for each coupe in the coupe register. This was compared with the volumes expected from the assessed volumes for the P.I. (Aerial Photo Interpretation) typing for the coupe. The A.N.M.

workings are particularly valuable in this way. as All logging is now done within a pre-marked boundary and ~~that~~ only one or two short periods of logging produce a clear coupe.

The findings from these records are summarised below:-

The P.I. types (strata) can be expected to produce the following pulpwood volumes (all figures in super feet Hoppus per acre).

EIA**, EIA*, EIA*	(a) 110,000 on mudstone and other wet sites.
	(b) 100,000 on limestone and other drier sites.
EIA	(a) 100,000 below 2000'.
	(b) 90,000 between 2000' & 2400' (c.f. E.2A).
EIB	90,000
EIC	(a) 70,000 in stands with a high stocking of younger trees (NOT included in typing).
	(b) 65,000 in single aged stands.
EID	50,000
EIF	Not logged generally. Probably under 10,000.

Although no extensive areas of E2 have been logged the following volumes per acre appear to apply so far for <u>E. regnans</u>. However, they are considerably too high for <u>E. gigantea</u> on Misery Plateau (Frankcombe 1963).

E2A	-	90,000
E2B	-	80,000
E2C	-	60,000
E2D	-	40,000

These volumes were arrived at by trial and error fitting for each coupe using the assessed volumes per type. They show an amazing consistency for all coupes on Sheets Huntly 4, 8 and 12, Ellendale 5 and 9, and Styx 1, 2, 5 and 6. Only in two areas is there any marked disagreement between expected and obtained volumes per coupe:-

(a) Near the junction of Huntly Sheets 4 and 8 at least near the Main Road, each type must have produced volumes close to that expected from one type better. A check with the mapping branch indicated correct typing but unusually large crowns per tree as seen from the photos. The most likely explanations are that the original stocking or the site favoured the development of relatively open grown trees, or that there was an appreciable stocking of suppressed, younger aged trees in this area quite invisible from the photos. The first explanation is untenable on the grounds that E1B stands elsewhere do not have extraordinarily large crowns even on the same sites. The second is more likely as these younger trees are almost always under the crown of the larger ones, and that the trees do, in fact, occur in groups so close that the crowns look like that of one tree. Stumps seem to indicate a density class one above that typed although no proper count has been made.

The reason that the younger trees occur so near to the older ones is because the later burns were extremely light and prepared no seedbed and removed no shade except where slash was accumulated at the bases of the then 16-60 year old Eucalypts.

(b) On the Eastern side of Sheet Huntly 12 there is an area typed E1C which produced E1D volumes. A check with the mapping branch showed that the density was actually high D. Similarly in this area E1B should read E1C.

In all other cases the typing has produced remarkably consistent results. They are so good that errors in the area cut-over or even slips in the addition of volumes logged can be found whenever the estimated volume disagrees markedly with the obtained volume. In several cases the boundary between two adjacent loggings has been re-mapped to its correct position by comparison and adjustment of areas of types to match volumes loaded out at each landing, e.g. L.23, P1, boundary is NOT along the old Dawson's Road but along a major gully to the North.

Wood Quality

Not only can volume differences be attributed to some site factor, there are also pulpwood quality differences. The company tests small lots of wood from each coupe. These lots are taken from logs after they arrive at Boyer and there is no description of the tree or of the exact place it came from. From these tests a sample figure of certain pulpwood qualities such as "burst" or "tear" are obtained. It is realised that an individual sample may be unrepresentative (e.g. one tree only, state of the grindstones at the time of testing etc.), but it is hoped to discover any correlation that may exist between wood quality and some factor of the site. To this end a map has been prepared by the company with a colour code of quality samples against the location of the various coupes they were taken from. This map should be overlaid with tracings of the various site factors such as tree height, age, fire history, soil etc.

Jackson (1956) has already suggested that shallow limestone soils produce a poorer quality timber than dolerite solifluction soils (W40 & W41), so that the soil map may be the most important.

PLATE 26 LOGGING AND BURNING

(a) Tractor logged, no seedtrees on far bank, a few culls. Seed trees in foreground to be logged after regeneration is established. Whole area understorey - felled and ready for burning.

Mt. Field West in background, Lawrence's Creek in gully. Soil - dolerite till.

(b) Highlead logged E.gigantea on rocky dolerite solifluction. Understorey (wet sclerophyll) flattened by logging.

(c) Area recently burnt after tractor logging and understorey felling. E.regnans on Permian solifluction over limestone.

PART I E. SILVICULTURAL PRACTICES

Slash Burning. At least as early as 1946 slash fires were considered as being beneficial for regeneration as well as a means of disposing of slash. Gradually slash burning became recognised as being imperative for regeneration at least in mixed forest areas.

These early burns (1946 to 1956) were not entirely successful generally because of relatively poor burning conditions or because of lack of seed trees. Of the spring burns attempted in 1950, 51, 54 and 59 NONE produced satisfactory regeneration. The best regeneration has occurred where the slash burns were made in February or March, or on the December 1950-January 1951 wild fire area (in the Tyenna Valley).

The research finding on *E. regnans* by Ashton (1956), Cunningham (1958) and Gilbert (1958), coupled with the introduction of the one-man chain saw and the mobile loader enabled full scale regeneration treatments to be started here late in 1958. These treatments now include the retention of some of the dominants as seed trees, the slash felling of all rainforest remnants and an awareness of the need to burn early in the autumn.

The first good general flowering for 5 years occurred in 1959. The first general slash burns after slash felling occurred in 1960. The combination of these two factors produced regeneration on all but a very small percentage of the areas treated. Even this small percentage was soon sown along with all unsuccessful slash burns of the previous two years.

Because of the need to get a hot burn, burning has to be done when there is still a chance of "blow-up" days occurring. Such a day occurred in mid-March 1961, two or three days after slash burning commenced. The fires that escaped on that one day re-burnt many of the 1958 and 1959 burns and most of the 1950 to 1954 burns. They also burnt some of the 1960 regeneration. Although a few hundred acres of good regeneration was destroyed this fire helped to make a complete change of the scale of the Florentine silvicultural operation. It has enabled large scale treatments to be economically carried out in areas where, because of relatively small patches of regeneration, only patchy and expensive treatments such as planting were previously considered possible. It has provided an early warning of the ease with which old burns burn again. It has opened very large bracken areas to treatment. These bracken areas would have had to be burnt anyway before re-stocking measures could be undertaken. In relative values this fire produced ten times as much good seedbed as the area of regeneration it destroyed. New treatments such as wind-rowing after the fire are now being tried to prevent this re-burning hazard.

Current Silvicultural Practices

(1) When an area has been selected for logging its boundary is marked in the field. If the area is not going to be high-lead logged, seedtrees are marked at a nominal rate of about 5 per acre. The seed tree marker chooses big crowned dominants of spar age or sometimes the old growth remnants in a mixed age stand. The selected trees are scattered as evenly as possible over the whole coupe.

(2) The Eucalypts (other than the seed trees) are felled and logged by tractor.

(3) The seed crop on the seed trees is assessed by telescope to determine when to burn the area.

(4) The understorey remnants are felled and the coupe is later burnt.

(5) In the spring following burning the regeneration is assessed and mapped and the understocked areas artificially restocked.

(6) Regeneration is protected by 1080 poisoning or trapping for the first year or two.

(7) The seed trees are logged with every care being taken to preserve existing regeneration. Large patches damaged by this logging are re-sown.

This pattern has a few variations such as high lead logging with seed trees, dosing of the understorey and the timing and intensity of understorey utilisation, or clear felling, burning and sowing.

This seed tree system worked very well for the 1960 slash burns when it produced excellent regeneration. In 1960 there was abundant seed from the 1959 flowering.

The problems associated with the present system of seed tree marking are as follows:-

(a) Difficulty in spacing marked trees.

(b) Impossibility of selecting "trees with seed" when marking.

(c) Damage to regeneration when extracting seed trees.

(d) Many trees without seed carried unnecessarily over to second logging.

(e) Hard to protect seed trees from fire if desired.

(f) Hard to assess crop on seed tree either before or after slash felling.

To overcome these problems it is suggested that the following system should be tried at least experimentally on the floor of the Florentine Valley and if proved more efficient should be adapted to other areas, and to more difficult topographies.

Seed Trees in Strips

(1) Mark boundary of coupe (D.W. Frankcombe of A.N.M. has suggested that a pair of coupes be marked for costing purposes, one a control, the other with seed trees in strips).

(2) Select loading points at about 5 chain intervals along the road.

(3) Run main logging tracks in from these loading points at about 5 chain intervals to cover the coupe.

(4) Ask fallers to leave all trees within 1 chain of these tracks but to fell all other trees. Collect seed off felled trees where available.

(5) From the tracks assess all retained trees for seed and mark only those that carry seed. Decide when to burn.

(6) Fell all other trees.

(7) Log coupe using original main access tracks.

(8) Fall understorey but keep access tracks clear wherever possible.

(9) Slash burn (after protecting the seed trees from humus fire if necessary).

(10) Assess regeneration.

(11) Log seed trees down access tracks.

(12) Sow unregenerated patches but leave access tracks themselves unsown.

The place of understorey logging in this scheme is obviously between (3) and (4) if the main access tracks are used and not obscured, or between (7) and (8) if damage to the understorey by the Eucalypt logging is not considered important. For the purposes of seed-crop assessment the first alternative is preferable.

This system means that only 40% of the total seed can possibly be retained on the seed trees. However, it does mean that 40% is guaranteed and no trees without seed are left standing. With flowering such as 1959 and 1961 this 40% would undoubtedly be adequate for 1960 or 1962 slash burns but it may be too little for 1961 or 1963 slash burns.

With a light crop of seed this 40% may be too little, but generally with a light crop there are fewer trees in flower rather than general light flowering meaning that even 100% in such years may not re-stock the coupe. All trees are then taken out in one logging and the area sown.

With a heavy crop, regeneration is ensured with 40% of the total seed and much of the remaining 60% may be collected for artificial sowings.

The costs of pre-cleaning main access tracks and of supervision of the plan are relatively light and this system would most likely reduce the overall cost of logging of the forest as a whole (rainforest species and Eucalypts) as well as that of regeneration treatments.

The advantages of the suggested system are obvious. The seed tree marking is simplified, most efficient use is made of tractors and mobile loading equipment, only trees with seed are left and if there is no seed all are taken in one logging. There is no hit or miss chance taken with the regeneration burn. Future management and protection is greatly simplified by the presence of well-spaced tracks.

Summary of Part I.D

(This section is very brief and mostly descriptive.)

Photo interpretation types bear a remarkedly consistant relationship to volumes logged. This is true for all loggings in the Styx and Florentine until the end of 1960. The relationship now appears to be limited to the floor or lower slopes of both valleys.

Summary of Part I.E

1. Spring slash burns are not to be recommended for regeneration by natural seeding.

2. Seed trees in strips are suggested as being a better regeneration system than scattered seed trees.

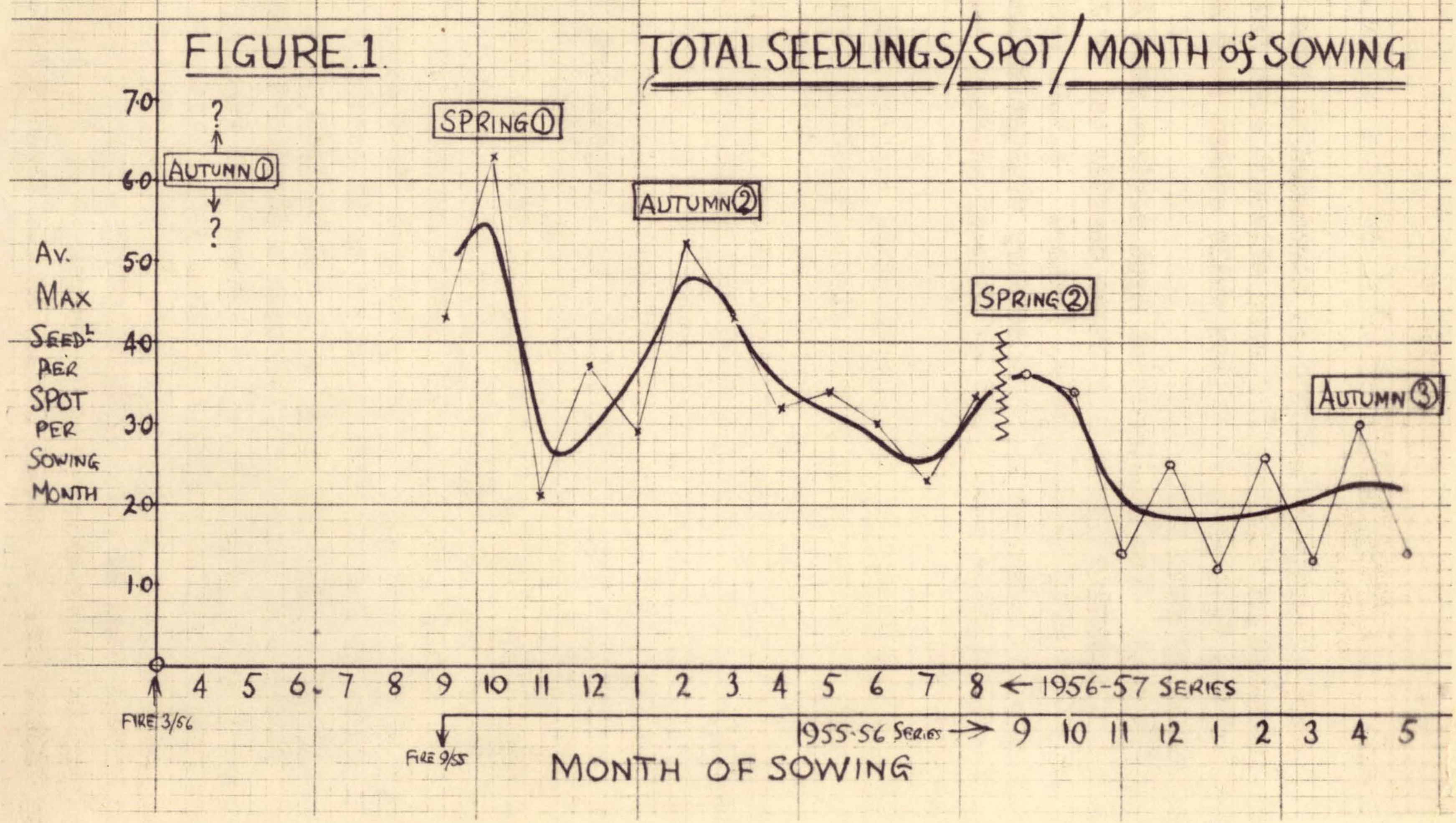


FIGURE. 1.
TOTAL SEEDLINGS/SPOT/MONTH of SOWING
AV. MAX SEED. PER SPOT PER SOWING MONTH
7.0
6.0
5.0
4.0
3.0
2.0
1.0
AUTUMN ①
SPRING ①
AUTUMN ②
SPRING ②
AUTUMN ③
4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 ← 1956-57 SERIES
FIRE 3/56
1955-56 SERIES → 9 10 11 12 1 2 3 4 5
FIRE 9/55
MONTH OF SOWING

PART II SUMMARY OF EXPERIMENTAL FINDINGS - JAN. 1957-JUNE 1961

Most experiments started or continued in this period are included in this section even although some failed to produce the desired information while others were not completed by June 1961.

A. Spot Sowings Two experimental spot sowings were laid out in the Florentine in addition to those carried out by J.M. Gilbert and R.L. Newman and K. Cremer. A.N.M. currently spot sow all areas on which secondary vegetation has seriously reduced the amount of mineral seedbed available for sowings.

Experiments 34 and 34A Experiment 34 was designed and laid out prior to January 1957 although sowing continued until May 1957. Experiment 34A was then designed to extend the experiment to cover the three winter months June, July and August 1957. All analyses and findings were written up in various reports from December 1957 to August 1960. In all 3,888 spots were sown and each inspected an average of 20 times. Unfortunately this huge experiment was practically destroyed in demonstrating the extreme effects of browsing animals. However, much valuable information was gained from it and this is summarised below.

(a) Time of Sowing Each series showed that the spring sowings were the best, but in each case these sowings were the first in the series and were made 6 or 11 months after the slash burn. The effect of this was to hide a real decrease in success with time, coupled with a fluctuation that tends to produce peaks in Spring and Autumn (see Figure 1). The real answer is very likely that it is better to sow at age 0 in most cases, otherwise in the Spring following an Autumn burn or in Autumn following a Spring burn. Sowing of unprotected seed in summer (Nov. to Jan. incl.) or Winter (May to August incl.) is not recommended.

FIGURE. 2

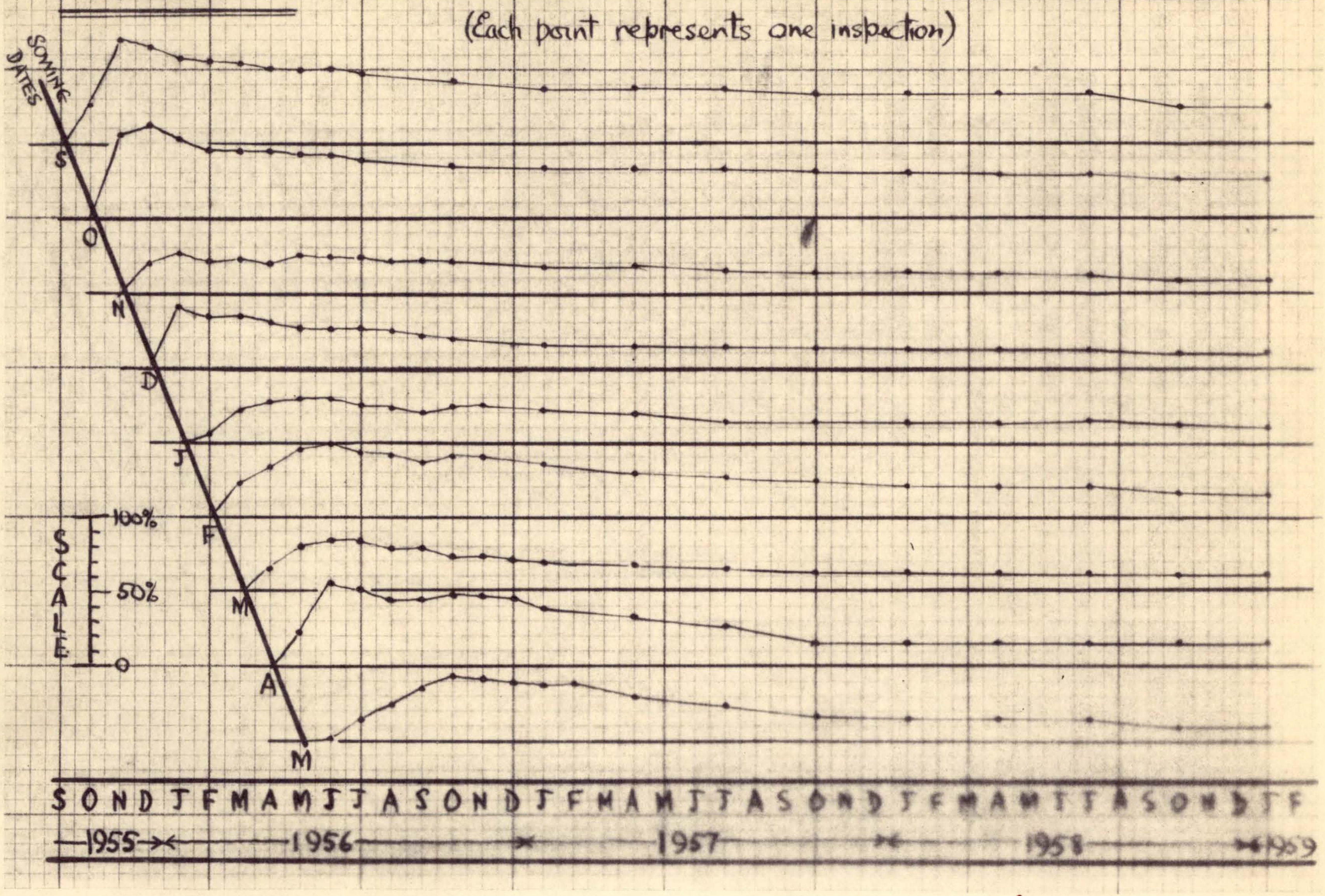

PERCENTAGE of SPOTS STOCKED. SERIES I, Exp. 34
(Each point represents one inspection)
SOWING DATES
S
O
N
D
J
F
M
A
M
SCALE
100%
50%
0
S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F
1955
1956
1957
1958
1959

Figure 1 was drawn using the following information:-

Series II & III Started in September after a March burn, that is 6 months of Winter after the Autumn burn, and continued for a whole year.

Series I Started in September a year after a September burn, that is 12 months or a whole growing season after the burn.

For comparative purposes the first sowing on Series I and the last sowing on Series III were the same interval from their respective burns in terms of growing seasons although not in months.

The graph is drawn through points which represent the maximum number of seedlings to germinate divided by the total number of spots sown for each month of sowing. Germinations, of course, occurred one to two months or longer after sowings.

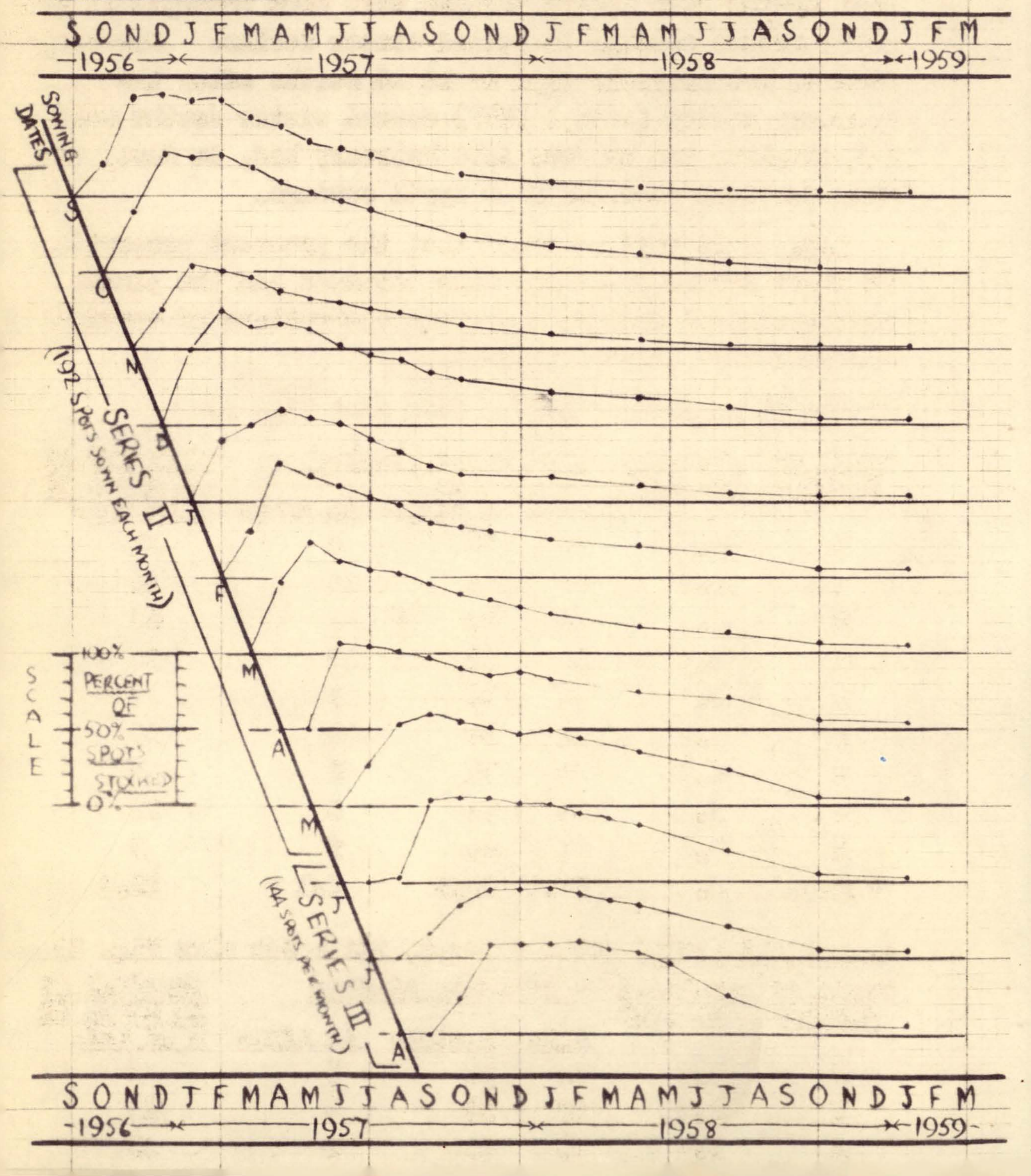
Sowings of protected seed (DDT etc.) were not made.

Series 1 Results (1955-6) (See also Fig. 2)

Month of Sowing	Av.Germs per spot	% Spots Stocked (Total 192) MAX.	9 mths.	18 mths.	Survival at 18 mths. as % of MAX.
S	3.6	76	53	40	53
O	3.4	66	40	34	52
N	1.4	41	22	18	44
D	2.5	47	21	14	30
J	1.2	41	25	15	37
F	2.6	60	41	29	47
M	1.3	39	23	14	36
A	3.0	66	41	16	24
M	1.4	52	40	18	34
TOTALS	2.3	54.2	34.1	22.0	40.6%

Sowings in September and October had the highest maximum number of spots to germinate, and the highest average germination per spot, and the best survival rate. February followed a similar pattern but April after a good start declined

FIGURE.3 SERIES II & III – EXPERIMENT 34 PERCENTAGE of SPOTS STOCKED



rapidly, especially between 9 and 18 months after sowing (Jan. 1957 to October 1957). Most losses occurred in the period July to October 1957. This suggests that for this series late autumn sowings were more susceptible than early autumn sowings to second winter deaths. However, this is not entirely true as at 18 months after the February sowing (August 1957) second winter deaths were not complete and by Jan. 1958 February had, in fact, the same survival percentage as April sowings.

N.B. It must be noted that the greatest proportion of these deaths would not have occurred had the plants been protected from browsing and the pattern of survival may have been quite different.

Series 11 Results 1956-57 (See also Fig. 3)

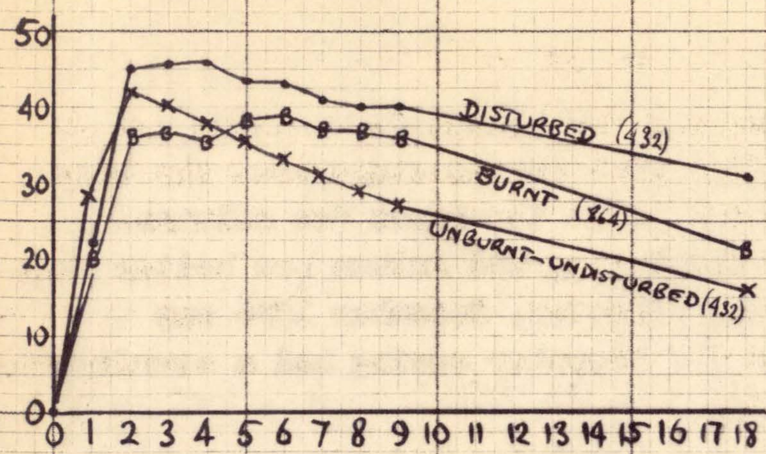
Month of Sowing	Av.Germs per spot	% of Spots Stocked			Survival at 18 mths. as % of MAX.
		MAX.	9 mths.	18 mths.	
S	4.3	74	32	8	11
O	6.3	89	41	14	16
N	2.1	62	24	6	10
D	3.7	86	35	13	15
J	2.9	74	19	5	7
F	5.2	81	30	16	20
M	4.3	79	31	6	8
A	3.2	68	34	8	12
M	3.4	71	46	5	8
TOTALS	4.0	76.0	32.5	9.1	12.4

Series 111 (1957) (This is Expt. 34A - See also Fig. 3)

Month of Sowing	Av.Germs per spot	% of Spots Stocked			Survival at 18 mths. as % of MAX.
		MAX.	9 mths.	18 mths.	
J	3.0	62	39	2	9
J	2.3	52	31	6	13
A	3.5	59	45	6	10
TOTALS	2.9	59.2	38.4	4.6	7.8

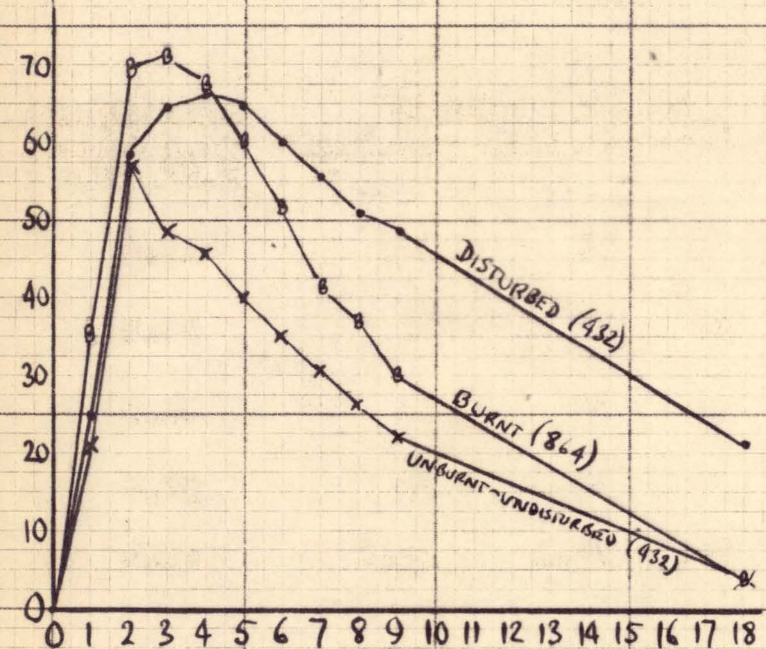
FIGURE. 4 – Exp. 34

SEEDBED



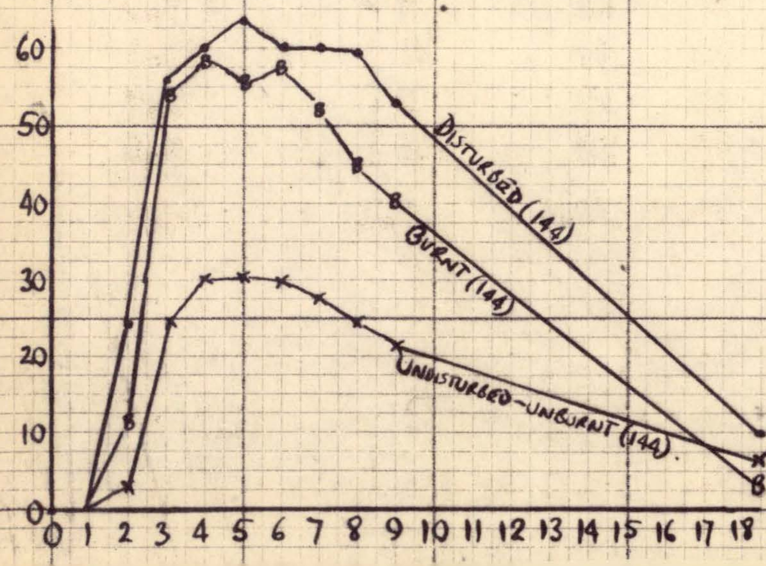
4A. Series I

1728 Spots, 9 Sowing Months
September '55 – May '56



4B. Series II

1728 Spots, 9 Sowing Months
September '56 – May '57



4C. Series III

432 Spots, 3 Sowing Months
June – August 1957

In Series 11 and 111 the losses to browsing are so great after the initial good germinations that the only real measure of success is in the first two columns. Again, germinations for Spring and Autumn are better than for Summer or Winter. However, December 1956 was particularly wet and the December sowing had a correspondingly unusual success.

(b) Site to Sow (See Fig. 4) For Series 1 and 11 four seedbeds were recognised, but for Series 111 both burnt seedbeds were considered as one.

Series 1

Seedbed	Av.Germs per spot	% of Spot Stocked MAX.	9 mths.	18 mths.	Survival at 18 mths. as % OF MAX.
Unburnt, undist.	2.7	52	27	16	29.6
Unburnt, dist.	2.6	61	39	31	50.8
Burnt, undist.	1.8	51	34	22	42.5
Burnt, dist.	2.0	53	36	20	37.4
TOTAL	2.3	54.2	34.1	22.0	40.6

Series 11

U/U	2.5	67	22	5	7.5
U/D	4.4	76	49	21	27.6
B/U	4.5	81	27	3	3.7
B/D	4.6	79	32	6	7.6
TOTAL	4.0	76.0	32.6	9.1	12.4

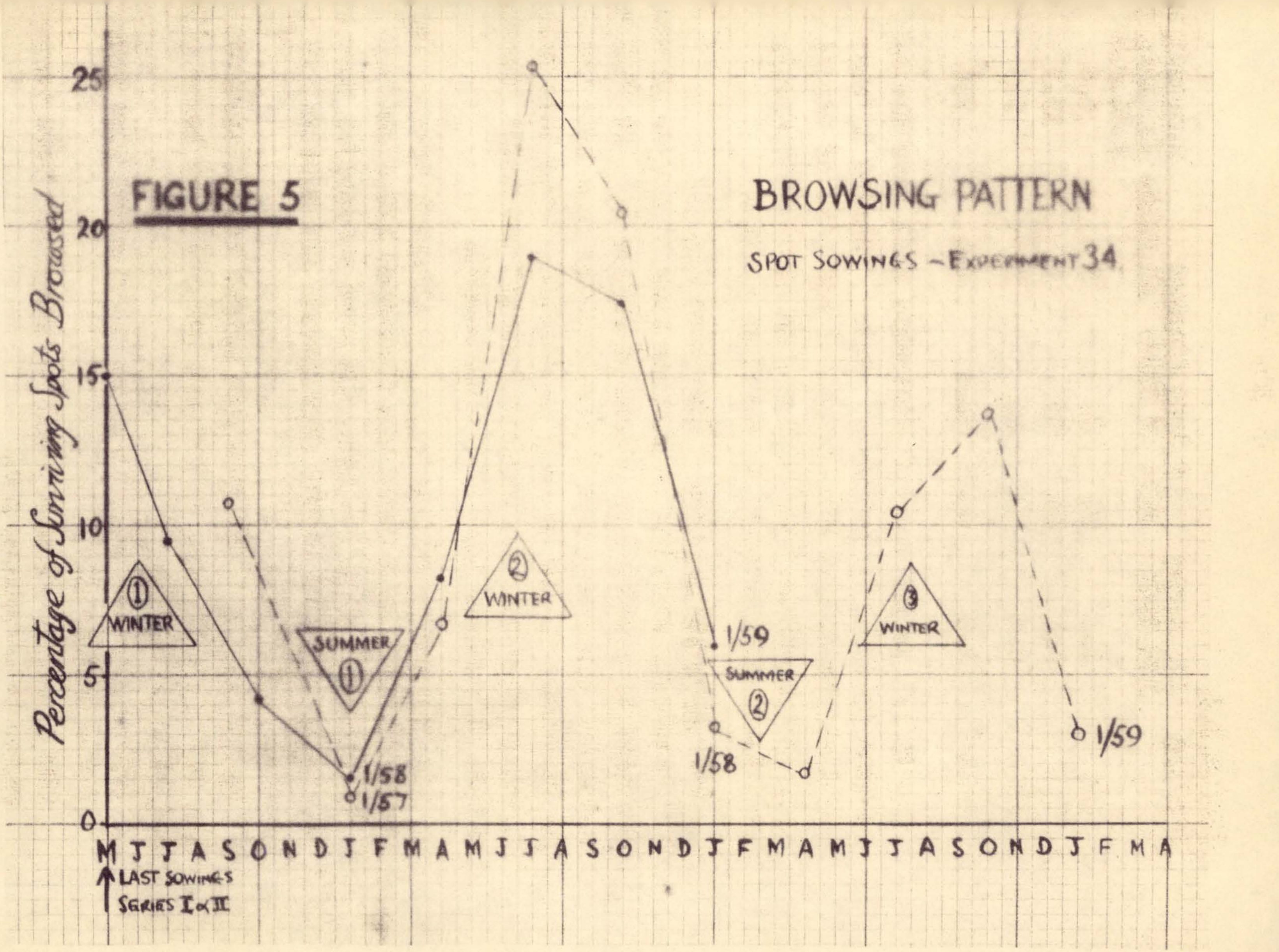


FIGURE 5
BROWSING PATTERN
SPOT SOWINGS - EXPERIMENT 34
Percentage of Surviving Spots Browsed
25
20
15
10
5
0
M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A
LAST SOWINGS
SERIES I & II
1 WINTER
SUMMER 1
2 WINTER
SUMMER 2
3 WINTER
1/58
1/57
1/59
1/58
1/59

Series 111

Seedbed	Av. Germs per spot	% of Spot Stocked MAX.	9 mths.	18 mths.	Survival at 18 mths. as % of MAX.
U/U	1.1	44	20	3	6.4
U/D	5.1	68	53	9	13.3
Burnt	2.8	61	42	2	3.3
TOTAL	2.9	59.2	38.4	4.6	7.8

In all series unburnt disturbed soil gave the best results in terms of numbers. Only Series 1, where the disturbance was incidental and not part of normal logging operations (Series 1 was on Highlead coupes), gave reasonable results in terms of growth.

(c) Browsing Pattern (See also Fig. 5)

Whenever browsing damage was seen on a spot it was recorded to produce the graphs in Figure 5. It will be seen that there are marked fluctuations from less than 5% in Summer to 20% or more in Winter. Even this marked fluctuation gives an under-estimate of the total browsing effect as denuded spots were not scored.

(d) Extension of Series 1 Although scoring for the experiment as a whole was abandoned after January 1959 it was decided to score the more successful part of Series 1 to follow height development and survival in close groups.

Height Growth The greatest height growth occurred on the tallest seedlings which were generally on burnt sites, e.g. August 1960:-

50% of all seedlings (146) on burnt sites were over 12' - tallest 32'.

50% of all seedlings (160) on disturbed sites were under 5' - tallest 24'.

50% of all seedlings (45) on unburnt sites were under 6' - tallest 17'.

Month of Sowing	S	O	N	D	J	F	M	A	M
Top ht.	32	31	30	18	23	20	13	26	13
Site of top ht.	B	B	B	D	D	D	D,U	B	U
Age, mths. since sowing	59	58	57	56	55	54	53	52	51
Ht/age ratio	.54	.53	.52	.32	.42	.37	.25	.50	.26

The tallest seedling from September, October, November and April sowings grew an average of 6" or more per month. As the growing season is seldom more than 6 months long this means that in the growing season they put on more than 12" per month.

The 32' tree put on the annual height increments of 1', 5', 9', 9', 8' for the five growing seasons.

Survival in Close Groups   Only where two seedlings of equal vigour were competing was the success of the spot in jeopardy. This was caused by the development of one-sided crowns liable to snow break. Otherwise a single dominant developed properly and eventually suppressed all other seedlings on the spot, especially if competing vegetation helps to cut off side-light. This last factor is probably the major cause of reduced numbers of seedlings per spot on burnt sites.

Summary of Expt. 34 & 34A Findings

1. Unprotected seed is best sown in the Spring or Autumn as close to the date of the fire as possible.

The germinations per spot curve shows marked fluctuations corresponding to Spring and Autumn sowings, combined with a decline with time since the fire. Although for any one growing season Spring may be better than Autumn, Autumn may be better than the following Spring.

2. In Summer the sown seed is subject to insect depredations unless the rainfall is high, (December 1956).

Seed sown in Winter is subject to fungal losses unless the Winter is mild (1960). The use of insecticides and fungicides could reduce these losses and would tend to reduce the fluctuations in the curve (Figure 1) by raising the trough level.

3. Unprotected seedlings are decimated by browsing damage which is at its peak in late Winter and at its lowest in mid-Summer. Browsing was undoubtedly the chief cause of damage to this experiment. If all spots had been protected from browsing it is believed that every month in Series 1 would have 30 to 50% of its spots now established and Series 11 and 111 40 - 60%, even with unprotected seed.

4. Overstocking of spots is unlikely to be a problem with E. regnans.

5. Height growth for at least the first 5 years is better on burnt sites. It is worst on heavily disturbed sites.

PART IIB BROADCAST SOWINGS

Experiment 66 - Broadcast Sowing on Bracken Areas

Two latin squares of 9 plots each 50L. by 50L. were laid out near the Settlement in April 1958 in an area of dense bracken burnt in March 1958. One trial was on a Northerly aspect with moderate log cover, the other on a Southerly aspect with moderate limestone outcrop cover and few logs. Sowing rates were 0, 1, 2 lbs./acre E. regnans seed dusted with D.D.T. In addition, a small observation plot some distance from the main trial was heavily sown. It was decided to leave the main trial quite undisturbed for a few years but to make periodic notes as to seedling growth on the observation plot.

Observations so far have been most discouraging with the few seedlings surviving still in the one pair of leaves stage under very dense bracken to four feet high. Powles in Victoria (1940) waited five years for his broadcast sowings to emerge above the bracken.

(K. Cremer reports complete failure of this sowing. 19.2.65)

Experiment 77 - Broadcast Sowings at Various Ages

This experiment was established in September 1959 in co-operation with K. Cremer who was then the A.N.M. Fellow.

The experiment was designed to measure the success of sowings against age of the logged-over seedbed. Other variables were - type of seedbed (burnt or disturbed); understorey type of previous forest (rainforest or wet sclerophyll); parent material (mudstone, dolerite or limestone) and the effect of browsing (fenced and unfenced plots).

The experiment covered several ages of cut-over with an initial range of ½ to 6½ years. Each area was sown over a period of two years to provide some overlapping of ages. This overlapping allowed the study of the effect of climate - e.g. W.72 was 1½ years old at the start of the experiment and W.59 was 1½ years old a year later.

Notes were made of the vegetation at the time of sowing in order to follow the secondary succession and its effect on the sowings. A joint paper has been prepared to cover the secondary succession on burnt seedbeds (see Cremer & Mount - 1965)

PART II.C. FLOWERING SURVEYS

An attempt was made to produce data for a "Flowering Map" by scanning the tree tops with a telescope from the tops of various mountains. Unfortunately, the climbs that were made to Mt. Field, Mt. Lord, Chinner's L.O. and Snowy No. 2 were in years of extremely poor flowering and with little knowledge of the flowering period. The method was abandoned in 1958. This was unfortunate because the years 1959 and 1961 were good flowering years and flowering could most easily have been mapped from such vantage points.

General findings from the survey, plus other observations are listed below:-

Period of Flowering

1. *E. regnans* Over the whole area in poor years (1957) flowering may not start until the end of May and yet an occasional tree may be flowering at the end of August. In good years (1959) flowering may start as early as the end of January and be quite over by the end of June.

2. *E. gigantea* flowered more regularly than *E. regnans*, usually from January to April.

3. *E. obliqua* flowered from about January to March.

One *E. gigantea* was observed to flower for over one month in 1957. All other trees seen flowered for shorter periods.

Years of Flowering

Cunningham (1958) showed that *E. regnans* at the Acheron River in Victoria flowered well in 1954, 1956 and 1958 and poorly in 1955, 1957. Ashton (1956) showed that *E. regnans* at Wallaby Creek produced the same pattern but that 1952 and 1956 was not as good as 1950 and 1954. Gilbert (1958) showed that of 45 coupes visited, 64% flowered in the even years 1952, 1954, 1956, only 4% in the odd years, 25% flowered annually and 7% showed a general poor flowering.

Observations made at this station are as follows:-

1957 Good flowering of *E. gigantea*, especially on slopes of Mt. Field, Wherrett's L.O., also some flowering on the Western fall of the Snowy Range.

E. regnans very poor, but some flowering seen East of P.13, under Mt. Lord and in the W.38 area, on S.6 and on the Burma Road.

E. obliqua hardly flowered at all.

1958

E. gigantea moderate flowering from Eden Creek to the Gap but not on slopes.

E. obliqua moderate flowering from Dewhurst's Quarry Road to the Gap and into the S. half of Tim Shea Block.

E. regnans good flowering but only in L.28, L.38 area (conglomerates) and near W.45, W.82 (shallow dolerite solifluction over limestone).

1959

E. regnans good general flowering over most of Florentine.

E. obliqua good flowering at least in Rd.8 area.

E. gigantea poor flowering.

1960

Poor flowering of all three species. Some *E. regnans* flowered at M.2, W.38.

1961

Good general flowering of *E. regnans*, at least from Lawrences Creek Northwards. Good flowering of *E. obliqua* at CH.2, *E. gigantea* on Misery Plateau and in Robertson's Creek area.

As Gilbert (1958) forecast the even year pattern has become an odd year one for *E. regnans*, although there is a strong possibility that for any one stand the pattern may be less regular, e.g. in 1956 there appeared to be a better flowering in the Eden Creek area than in 1961. The 1961 flowering appeared to be more general to the North of this area.

PART II.D. EXPERIMENT 79 - THE FATE OF SEED SHED IN CAPSULES

This experiment is only in its early stages. However, the following observations may be of importance:-

(1) At the October 1960 sowing at Rd. 8 Euander bugs were observed "mining" capsules on twigs that had been placed there in July 1960. These insects were only interested in certain seeds, presumably the viable ones, which, when they had freed them from the capsule, they carried off at great speed. Euander activity was only seen here on the open burnt seedbed of the February 1960 slash burn and not under dense wet sclerophyll or rainforest understorey. However, under such understoreys the capsules had hardly started to open.

(2) Rotting of the shell of the capsule appeared to be extremely rapid under wet sclerophyll understorey and slowest in the open.

(3) After only 6 months the capsules are generally very hard to find due to leaf fall in forest or to moss and marchantia growth in the open.

PART II.E. SECONDARY SUCCESSION

Experiment 36 - Regrowth under Wattle

A tenth acre sample plot was established in October 1954 to follow the development of E. regnans and E. obliqua regeneration beneath a dense stand of A. dealbata.

Dense wattle occurred on all but about one-fifth of the plot. This one-fifth was lightly disturbed soil and it carried almost pure Eucalypts of a much closer spacing than those growing in the wattle. In the wattle area the Eucalypts are far fewer per acre than the wattle.

This shows that the secondary succession in this case was chiefly to wattle on the burn and to Eucalypts on the disturbed sites. If an equal rate of seeding occurred on both sites (as is likely) the results in terms of relative numbers per acre of Eucalypts agree with the spot sowing results (e.g. Fig. 4, Expt. 34, page 99).

In terms of height growth there was also agreement for the first few years when the seedlings on the burn were taller than those on the track. But following two severe defoliations of the wattle the Eucalypts on the burn have lost their height advantage to those on the track and have started to put on a greater girth increment instead.

This suggests that the initial advantage in height growth on burnt seedbed over that on disturbed may disappear. The initial advantage in numbers on disturbed over those on burnt may also be made up for by the trees on the burn putting on greater girth once the shrub competition is overcome. However, the disturbed site must have one major advantage in this area - it has produced only Eucalypt wood.

At Rd. 8, after slash felling the old rainforest, the 1960 fire produced a stand consisting almost entirely of

PLATE 27 SECONDARY SUCCESSION

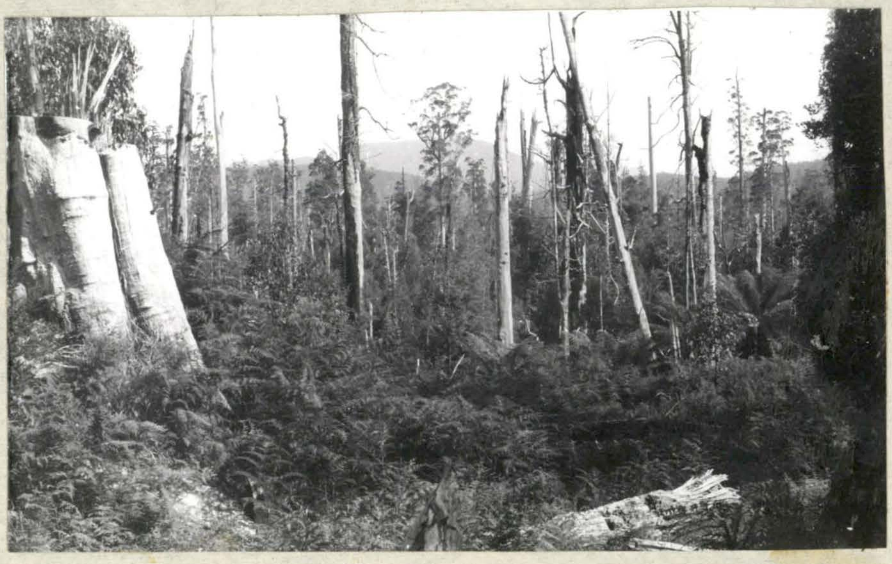
(a) Marchantia. This 90% cover of Marchantia followed a spot fire which occurred 12 months before this picture was taken. (K. Cremer in photo)

(b) Polytrichum. Pteridium is seen here just starting to invade the 2" mat of Polytrichum juniperinum. No "higher" plants have survived the browsing which has been almost unchecked since the fire 3 years ago. The polytrichum mat succeeded the fire mosses Funaria and Ceratadon.

PLATE 28 BROWSING AND THE FERNS

(a) The top picture shows the effect of fencing at age 6 months. Both inside and outside the fence was sown at the same time. Inside the fence is a shrub thicket and no ferns. Outside the fence is a sea of "wet ferns" and no shrub or tree seedlings.

(b) Below is a 9 year old area unprotected from browsing in which the wet ferns have been laregly succeeded by Pteridium. This area had no bracken before logging. The initial establishment of bracken seems to be from a few special niches like burned out stumps which favour the development of bracken spores.



Eucalypt. Such a stand cannot be produced by burning younger areas because of the dense Wattle or Pomaderris regrowth which also arises. Rd.8 may have had the advantages of the normal disturbed seedbed plus those of the burnt seedbed without any of the latter's disadvantages.

Experiment 77 / SECONDARY SUCCESSION AFTER LOGGING AND BURNING. The results of the secondary succession part of this experiment will be published in more detail in a paper by Cremer and Mount. The main findings are summarised below.

(i) The burnt seedbeds sampled in this experiment were 99% covered with vegetation by age 1½ years.

(ii) On sites that previously carried rain forest understories the secondary vegetation is chiefly dense Marchantia unless the summer following the autumn burn is extremely dry or hot. In this case the Marchantia dies back and is replaced by a relatively sparse stocking of Fumaria and Ceratadon (the fire mosses) and a dense Erechthites stand.

(iii) On sites that previously carried wet sclerophyll understories the secondary vegetation pioneers are the fire mosses.

(iv) Both the fire mosses and Marchantia are succeeded by Polytrichum juniperinum and to a lesser extent by Campylopus introflexus. Herbs such as Hydrocotyle are more important on the dryer sites.

(v) Browsing by native animals may prevent the development of sufficient tree and shrub regeneration and allow the site to become dominated by the "wet ferns" Histiopteris and Hypolepis. These ferns will be succeeded by Pteridium except in shaded places.

(vi) Lack of browsing may produce a shrub thicket, with or without eucalypts, which will bypass the fern stage.

<u>Summary of Part II</u>

<u>Experimental Findings 1957-61</u>.

1. Untreated seed should be sown in <u>Spring</u> or <u>Autumn</u> and not in <u>Summer</u> or <u>Winter</u>. Moreover it should be sown as soon after the fire as possible.

2. Disturbed sites can support more seedlings than burnt, but they generally have an initial height growth disadvantage.

3. Browsing shows a marked winter bias.

4. April broadcast sowings of eucalypts on <u>Pteridium</u> sites burnt only one month earlier are unlikely to suceed.

5. Good flowerings of <u>E.regnans</u> occurred in the Florentine in 1959 and 1961.

6. On the floor of the Florentine burnt seedbeds are 99% recolonised by age 1½. <u>Marchantia</u>, <u>Funaria</u> and <u>Ceratadon</u> are the chief pioneers.

PART III REGENERATION SURVEYS

Introduction

This part of the thesis outlines the development of regeneration surveys in other parts of the world and then goes on to discuss surveys made at Maydena and their results.

The final section deals with one field of regeneration survey theory - "heterogeneity", or clumpiness, and its measurement. Existing heterogeneity factors are discussed and a new factor proposed and tested.

PART IIIA REGENERATION SURVEYS IN OTHER PARTS OF THE WORLD

In any one area it is bound to be fairly late in the development of forest exploitation that regeneration surveys are required. Nations with no natural forest need no measure of regeneration other than the usual "survival counts" in plantations. Nations with ample forest generally concentrate their efforts on removing the forest to make way for agriculture and are only much later interested in maintaining or re-establishing them. However the older plantations are often re-stocked by natural regeneration, and agriculture gradually comes to terms with native forest as the latter's value is realised. Once there is dedication of areas for forestry purposes these areas have to be regenerated after logging. This is when regeneration surveys are required.

Regeneration surveys probably started as qualitive field observations of regeneration old enough to be easily seen from a walking position. The stocking, if estimated, was expressed as an average spacing or as a number of stems per acre. Gradually it was realised that these observations were subject to great bias caused by access, observer and other factors. To reduce the bias a method was developed of counting seedlings on small quadrats systematically located over the whole area. This measured the stocking as the product of the mean number of seedlings per quadrat (hereafter called "density" (d)) × the number of quadrats which would make up an area of an acre giving the score for the area in terms of "trees per acre".

Lowdermilk (1927) was unsatisfied with this measure of stocking because a few well stocked quadrats could produce a reasonable density and give a satisfactory number of trees per acre, even if the area was mostly bare. He suggested that a better expression of stocking would be the percentage of the quadrats sampled that contained at least one seedling. This term is called the "Frequency" (f) of quadrats stocked. Lowdermilk also suggested that the quadrat size should be standardised at one thousandth of an acre or "milacre".

Lowdermilk's idea was that each of 1000 well-spaced seedlings per acre would initially require a milacre in which to grow. Haig (1931) showed that this was unreasonable because natural seedlings were not "well spaced" and his studies in Western White Pine suggested that only 250 trees would eventually fully stock an acre. Haig then proposed a standard "4-milacre" quadrat in preference to the milacre. These two quadrat sizes have been most commonly used for all subsequent regeneration surveys.

It was soon realised that 100% frequency with either quadrat was both very rare and obviously well above the minimum stocking. It did not even occur in the densest natural regeneration because of the presence of stumps, logs and other non-seedbed surfaces which could not regenerate. This led to the nomination of "Minimum Stocking Standards" which were expressed as frequencies of milacre or 4-milacre quadrats. These are discussed later.

PART IIIB REGENERATION SURVEYS IN TASMANIA

Early Regeneration Surveys in the Maydena Area.

In 1948 F.P. Frampton of the Tasmanian Forestry Commission made a qualitative assessment of regeneration on the Lower Styx and Tyenna Valley areas logged by the Australian Newsprint Mills. Although the 1951 fire changed many of the areas he covered, elsewhere his findings were verified by "stockmapping" ten years later. His recommendation to burn a large part of the logged area to obtain regeneration was vindicated by the 1951 wild fire which successfully regenerated 900 acres. A further 300 acres which escaped this fire remained unregenerated until treated 10 or more years later.

In 1950 permanent milacre quadrats were established in the Tyenna and Florentine Valleys to follow the development of regeneration. However these quadrats were purposely sited on areas not already regenerated to see if they did regenerate and they cannot be called a regeneration survey as such.

Experiment 13D Permanent Transect Plot

In 1953 a 3 acre transect was established in the Florentine near the Main Road/Rd.9 junction through burnt (3/53) and unburnt, cut-over old mixed forest. Two degrees of burning and disturbed and undisturbed-unburnt sites were mapped on 30 pairs of 1/10 ac. plots.

The transect was sampled in November 1957 with the following results:- (1 milacre randomly selected in every 1/10 ac. plot)

Site	£	Trees per acre	Remarks
Well burnt	35.3%	900	Hot burn-good seedbed.
Lightly burnt	0%	0	Poor burn produced no seedlings.
Disturbed 1)	60.0%	2700	Maximum seedlings where track through burn.
Disturbed 2)	0%	0	No seedling where track through unburnt.
Unburnt	4.7%	48	1 cotyledon only. Not likely to survive.

These results clearly show the need to burn and burn well and that the disturbed soil (heavy clay here) only regenerated in the burnt area.

The Establishment of the Maydena Research Station.

In October 1954 the Maydena Research Station was established and R. Levingston appointed to it. The chief task was to assess the regeneration following logging, and study the way of improving it.

Permanent milacre quadrats were established on all cut-over areas in the Florentine and Styx Valleys at a 10 by 10 chain spacing. These quadrats were inspected annually and reports made of the stocking in terms of frequency and density (per acre) for large groups of coupes or for forest blocks. Logged areas in the Tyenna Valley were sampled using milacres for Risby's Basin, and 8' radius plots for Chrisps, Sunshine, Nicholl's Spur, Kallista and Burma Road; all at 10 by 10 chain spacing.

Altogether by January 1957, 612 plots had been established and 430 of them re-inspected by R. Levingston, some several times. This sampled more than 6000 acres of cut-over forest.

In January 1957, A.B. Mount was appointed to take over from R. Levingston and was put in charge of the station from March 1957 to June 1961.

During 1957 information for the Styx and Florentine was doubled by establishing circular milacres mid-way between the existing plots to produce a 5 by 10 chain grid.

Early Analysis of Milacre Results

In October 1958 all milacre survey results from the Florentine and Styx loggings were grouped into forest types, logging method and treatment subsequent to logging.

The results are summarised as follows:

Milacre Frequency (no. of milacres in brackets)

Types & Area	Years since fire (or since logging if unburnt).				
	1	2	3	4	5
Unburnt standing rain-forest understorey remnants. Tractor. 2626 acres.	2.5 (112)	4.8 (185)	3.9 (207)	3.2 (154)	5.9 (68)
Unburnt wet-sclerophyll understorey, some 1934 advance growth. Tractor 1702 acres.	11.0 (146)	15.3 (150)	17.4 (119)	19.0 (21)	16.7 (12)
Unburnt. Highlead 453 acres	2.3 (44)	0 (29)	0 (29)	21.4 (21)	20.0 (5)
Burnt. Tractor 1081 acres	25.0 (16)	19.7 (66)	27.3 (66)	22.2 (54)	18.3 (93)
Burnt in patches with some 1934 advance growth Tractor. 91 acres.	-	33.3 (6)	25.0 (12)	41.7 (12)	53.0 (17)
TOTAL 6151 acres	7.1 (340)	10.7 (448)	11.0 (456)	11.4 (264)	16.7 (204)
Corrected frequencies (see text)	9.0	10.7	11.0	11.4	12.4

The purpose of this analysis was to see what treatments favoured regeneration and to see if the regeneration position improved with time. The first part showed that all areas with standing rainforest remnants did not regenerate unless burnt, and that unburnt highlead areas which had had rainforest understorey did not regenerate. As a result of this analysis coupes of neither type were surveyed until treated to obtain regeneration.

The answer to the second question was somewhat biassed. The analysis indicated that there was an improvement in stocking of nearly 10% over the four year period Year 1 to Year 5 after logging. This is misleading for the following reasons:

Year 1 is made up of 1954 loggings surveyed in 1955
1955 " " " 1956
1956 " " " 1957
1957 " " " 1958

But as surveys only started late in 1954 there is no data of 1953 loggings surveyed in 1954. The importance of this lack is that 1953 was by far the best year for regeneration before 1960. Years 2, 3, 4 all covered 5 years of logging and all had 1953 regeneration.

Year 5 had only 4 years of logging 1953, 1952, 1951, and 1950. Year 5 therefore had too high a proportion of the good regeneration.

The final row of the table contains an attempt to correct this bias by adding the extrapolated data of the 1953 area to the first column the extrapolated 1954 data to the last column. It is considered that the resulting 3.4% rise in frequency from Year 1 to Year 5 is much more realistic than the 9.6% first obtained.

<u>Stock Mapping</u>

The older logged areas of the Tyenna Valley were first regeneration surveyed using 8' radius plots with a 10 by 10 ch. spacing which was subsequently reduced to 10 by 5 ch. By 1958 it appeared that these areas were practically closed to further regeneration and it was decided to develop the system of "Stock Mapping" which is described in "Standing Instructions for Regeneration Surveys" in the Appendix. Briefly the method consisted in a count of the taller seedlings on 20% of the area.

In all 2435 acres were assessed, counting all the trees visible on 4274 1/10th acre plots sampling 17.6% of the area. The more important findings are listed below:-

1. Unburnt logged areas with standing rain forest understorey remnants did not regenerate ....303 acres.
2. Areas burnt after logging regenerated well except where the burn had been poor or where seed was destroyed in

the fire. e.g.

Regenerated	1529 acres
Unregenerated gullies (poor burn).	172 acres
High-lead areas (No seed)	255 acres
Other unregenerated areas	176 acres
Total unregenerated burnt area ..	603 acres

In 1959 all old burnt areas in Tim Shea Block at the Southern end of the Florentine were "stockmapped" with a nominal sample of 40% of the area. The results of this survey are covered by the APPITA paper (See Appendix).

The Styx Experimental Survey

The extensive permanent milacre survey had produced some valuable information per type but it gave no worthwhile information about the stocking on individual coupes. It was decided to intensify the survey to obtain such information.

In order to choose the best type of survey a very intensive milacre survey of over 2000 milacres (spaced 1ch by 1/4ch) was subsampled to produce surveys of various intensities. The survey was carried out in December 1958. All subsamples were tested for the following:-

1. to see if samples with a spacing of 5ch by 1ch, to 2ch by 1ch, or 3ch by 1/2ch could give reliable estimates of the "true" frequency.
2. to see if these samples could enable the understocked areas to be mapped out with sufficient accuracy.

The results were somewhat disappointing although it was found that milacre spacings of 4ch by 1ch, 3ch by 1ch, 2ch by 1ch, and 3ch by 1/2ch gave reasonable estimates of the average stocking percent for the coupe as a whole, only the 2ch by 1ch survey gave a reasonable estimate of the proportions of the coupe stocked or understocked. No survey gave an accurate map of the location of these areas.

The survey strips were re-run in July 1959 to take down strip line information on stocking to be combined with various subsamples but even with the extra information mapping was only slightly improved.

The Development of the Standard Milacre Survey Method

As a direct result of the Styx Experimental Survey the standard spacing of quadrats was made 4ch by 1ch reducing to 2ch by 1ch for marginal areas, e.g. if the 4ch by 1ch survey produced a frequency close to 30% or if the area surveyed was so small that less than 100 quadrats were sampled, the information was doubled by running the intervening strips to produce a 2ch by 1ch survey.

A further development was the recording of stocking information outside the milacre. It became obvious that, if 30% stocked milacres is acceptable, the observer should make some judgement in the field as to whether an unstocked milacre was one of the 70% in a stocked area, or whether it was in an unstocked area. At first the stocking was investigated in an undefined "surround". This was later amended to inspection of a four milacre plot concentric with the milacre plot. This inspection of the 4 - milacre proved most valuable for mapping the boundary between stocked and under-stocked areas.

Two test surveys were run to check the maps produced by the 4ch by 1ch surveys. The tests comprised the running of the intermediate strips. Although minor alterations were made to the boundary the rather more regular and larger "area to be re-sown" was not altered in either case. In one case the original and the test surveys both picked out an unstocked area later proved to have been omitted by a negligent sower.

The standard method was thoroughly tested in the extensive survey following the 1960 regeneration burns. It is detailed in the "Standing Instructions for Regeneration Surveys" written by the author in 1961 (See Appendix).

Reconnaissance Survey in the 1959 Burnt Area.

In January 1959 a fire which originated near the junction of the Florentine and the Derwent burnt fiercely through some excellent *E.regnans* and poorer *E.obliqua* stands in Misery and Jungle Blocks. The regeneration under fire-killed *E.regnans* and severely fire damaged E.obliqua was sampled with a few strips subjectively placed with a milacre spacing of 1 chain. At the time of the sample (November 1959) the regeneration was found to be adequate in the unlogged stands but it was negligible after salvage logging or in fire killed stands of regrowth.

Subsequent inspection in 1961 showed that even in the unlogged stand the regeneration was almost non-existant because of browsing damage.

Regeneration Surveys in the North West Division

In March 1961 two weeks were spent assessing regeneration near Burnie and Smithton, and in instructing the Divisional staff in the use of the methods developed at Maydena. It was found that regeneration conditions were very similar to those found in the Maydena area with the important exception of the Surrey Hills basalt area. On the loams of basalt origin eucalypt regeneration in certain vegetative types occurred quite well without fire. All tracks regenerated quite well except for small compacted areas. Even undisturbed seedbeds regenerated to some extent in patches having little logging slash and a light cover of wet sclerophyll understorey species. These conditions are probably very similar to those which controlled the regeneration that occurred on a few unburnt highlead areas on shallow dolerite in the Florentine.

Regeneration Surveys in the Southern Division

In August 1961 a further two weeks were spent assessing regeneration on the Esperance burn. One of these surveys at Tyler's Hill gave misleading results because of two factors. The first was that this particular area had the densest regeneration of understorey species ever seen and that this regeneration overtopped the eucalypt seedlings. The second fault was that an August assessment after a summer fire was probably too early in that year (or in that area). The standard technique was chiefly based on September assessments of February 1960 burns in the Florentine where most of the regeneration was from autumn germinations. In August 1961 at

Tyler's Hill much regeneration was still to come.

It is now standard practice to assess autumn seedings the following autumn. Although any restocking measures have to overcome greater competition, this disadvantage is outweighed by the two advantages that the minimum effort is spent on restocking and that autumn is the best time to see if the seedlings require protection from browsing animals.

Summary of Part IIIA & B

Although quadrat regeneration surveys have been in general use in North America for 40 years they were not used in Tasmania to any extent until the foundation of the Maydena Research Station some 10 years ago. The early surveys at Maydena helped to show what types of forest could be expected to regenerate but they were generally too extensive to give much information about particular logged areas.

From 1958 to 1960 two new types of survey were developed, one for old areas on which the regeneration was established and overtopping it's competitors ("Stock Mapping"), and the other for areas logged and burnt 1 to 2 years previously. From the time that the "Standing Instructions for Regeneration Surveys" was written in 1961 these two methods have been standard practice throughout Tasmania.

PART IIIC A NEW HETEROGENEITY FACTOR

Introduction

This section explains the derivation and properties of the heterogeneity factor "h" first used in the APPITA paper of November 1961 (Copy in Appendix).

The frequency histogramme of numbers of seedlings per quadrat is not investigated in this section as it has been well covered by several other authors (Neyman 1939, Thomas 1949, Thompson 1952 and Ker 1954), but the analysis of the Styx Experimental survey seemed to indicate close agreement with the negative binominal distribution. Investigations along these lines were discontinued when it was realised that none of the parameters suggested by these authors had much application in the regeneration survey field. The parameters of the negative binominal are not convertable from one quadrat size to another. Regeneration surveys are far more concerned with the mean density and the frequency of quadrats stocked than the frequency histogramme of numbers of seedlings per quadrat. However a possible link is postulated at the end of this section.

Measures of departure from randomness will be discussed where they relate frequency and density as opposed to such measures as the mean/variance ratio which is only indirectly related to frequency.

The Need for "Heterogeneity Factors"

When frequency was first measured it was expected to simplify the assessment of populations. Counting seedlings on quadrats is a tedious business. Even when counts were made and a mean calculated, this mean did not indicate how the seedlings were distributed. With frequency it was at least possible to get some indication of the distribution.

Unfortunately frequency bore no recognisable relationship to the size of the quadrat as the mean had done. Moreover there was a definite need for information to be in recognisable terms such as "seedlings per acre". Stocking in terms of "X%

milacres stocked" meant very little. It didn't even mean X% of the area was stocked or that two distributions with X% milacre stocking need look in the least alike or have comparable means.

There was therefore the need for some way of doing the following:-

(1) Relating frequency data to density data.
(2) Comparing frequency data for different quadrat sizes.
(3) Obtaining a measure of aggregation especially in relation to the mathematically based Poisson distribution.

The Poisson distribution was nominated by Gill (1950) as the homogeneous distribution. The more gregarious distributions were called "heterogeneous" and the more even distributions were called "regular". As most natural distributions appeared to be "heterogeneous" the most pressing need was for a "Heterogeneity Factor".

<u>Factors Proposed by Other Authors</u>

Several authors have tried to find a relationship between the observed density "do" and the random density "dr" equivalent to the observed frequency "f". As "dr" is mathematically related to "f" it was hoped to discover a mathematical model relating "do" to "f" through "dr".

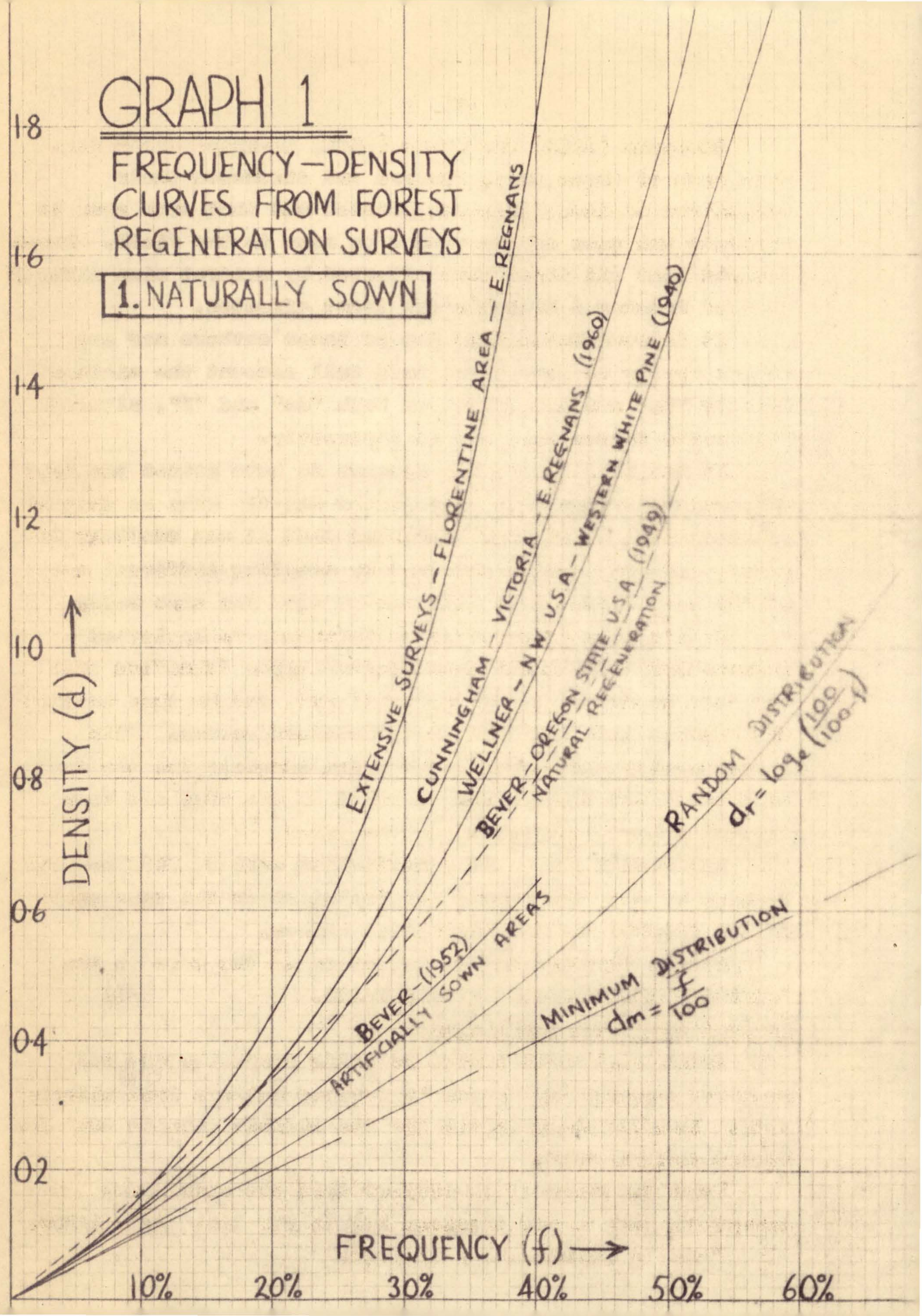
$$\left(dr = \log_e\left(\frac{100}{100-f}\right) \right)$$

The three most important ratios are as follows:-

McGinnies (1934):- do/dr

Fracker & Brischle (1944):- $\dfrac{do - dr}{dr^2}$

Whitford (1949):- $\dfrac{100do}{f^2}$


GRAPH 1
FREQUENCY–DENSITY CURVES FROM FOREST REGENERATION SURVEYS
1. NATURALLY SOWN
EXTENSIVE SURVEYS – FLORENTINE AREA – E. REGNANS
CUNNINGHAM – VICTORIA – E. REGNANS (1960)
WELLNER – N.W. U.S.A. – WESTERN WHITE PINE (1940)
BEVER – OREGON STATE U.S.A. (1949) NATURAL REGENERATION
BEVER – (1952) ARTIFICIALLY SOWN AREAS
RANDOM DISTRIBUTION
$d_r = \log_e\left(\frac{100}{100-f}\right)$
MINIMUM DISTRIBUTION
$d_m = \frac{f}{100}$
DENSITY (d)
FREQUENCY (f)
1·8
1·6
1·4
1·2
1·0
0·8
0·6
0·4
0·2
10%
20%
30%
40%
50%
60%

Thompson (1952) and Evans (1952) compared field data with each of these three factors and discussed their respective merits. Thompson pointed out that none seem to indicate the size of the clumps as seen in the field. Evans decided that all three were effected by quadrat size although that of Fracker & Brischle was least affected.

It is remarkable that non of these authors nor any others appear to have taken into full account the minimum density "dm" and its effect on both "do" and "f", although Whitford's factor does use it indirectly.

It was Gill (1950) who appears to have coined the term "Heterogeneity Factor". His factor was the same as that of McGinnies but he further suggested that it was constant for a range of frequencies obtained by sampling different areas of the same forest type with quadrats of the same size.

Gill's data is not very satisfactory as he plotted information from different seedbed types, "conifers only" and "all seedlings including conifers", and he then treated his data as though it was from a uniform source. His heterogeneity factors of 3 and 5 are adequate for the data as a whole but they appear to start in one type and move through other types one after the other.

The really important contribution made by Gill was his drawing of the "systematic" distribution on the same graph as the Poisson and his calculated curves.

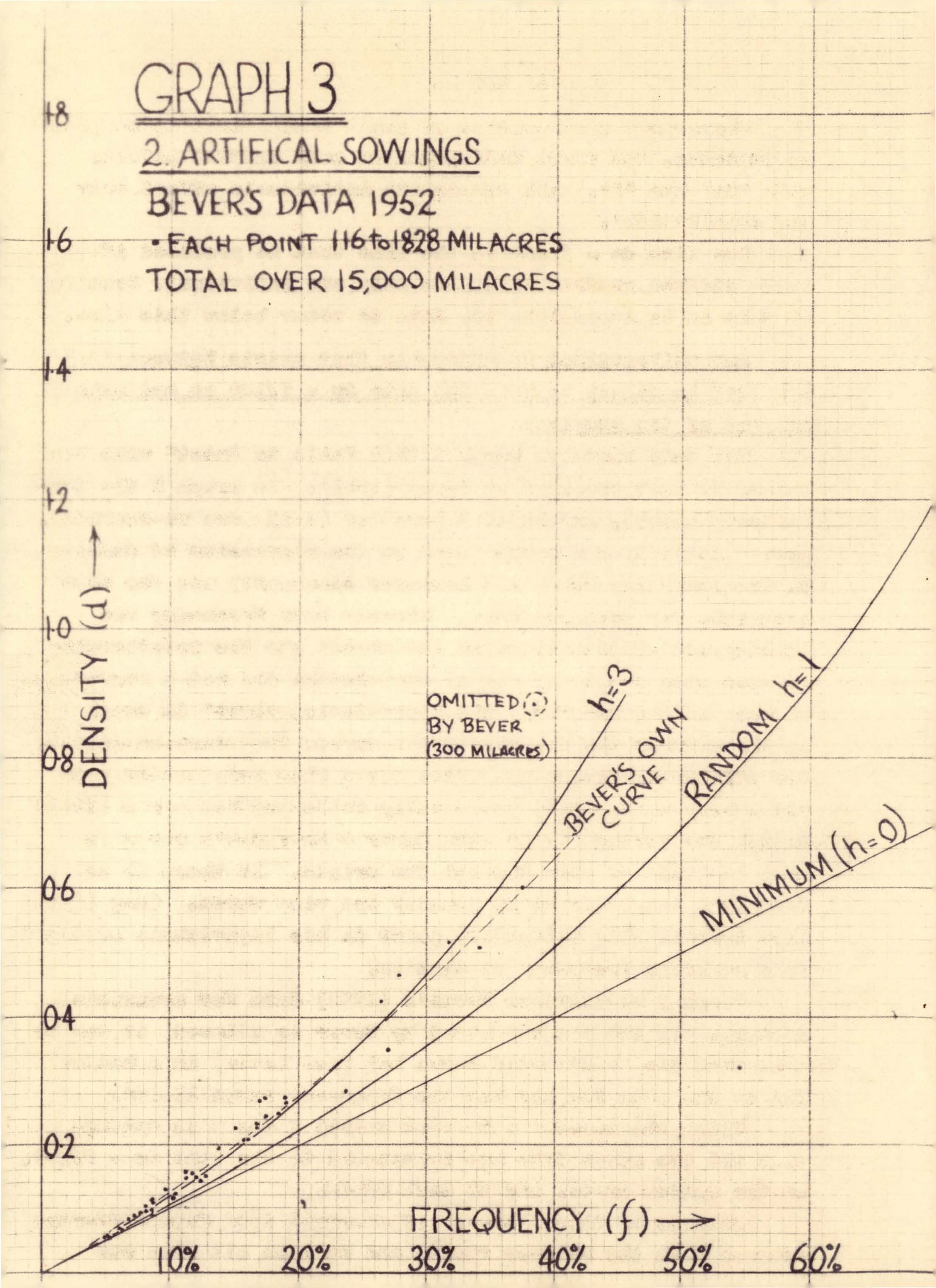
Gill's "systematic" distribution is the same as the "minimum" distribution $dm = f/100$.

<u>Derivation of the New Factor</u>

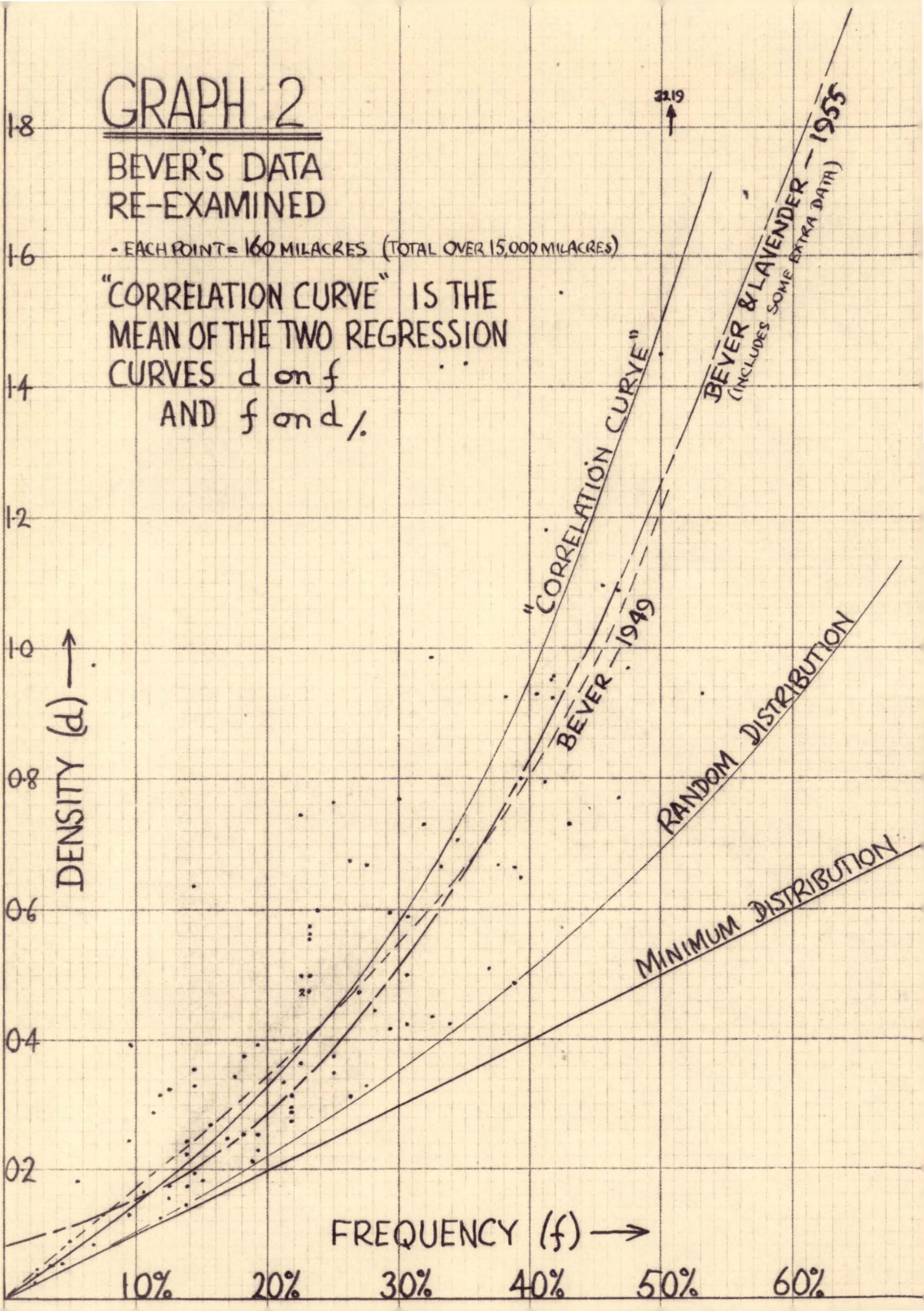
Graph No.1 shows curves relating frequency "f" and observed density "do" drawn by various authors from milacre data. It also shows curves for the minimum density "dm" and random density "dr".

From the graph it is obvious that all curves are asymptotic not to the abscissa but to the line $dm = f/100$.

This is explained as follows:-



GRAPH 3
2. ARTIFICAL SOWINGS
BEVER'S DATA 1952
• EACH POINT 116 to 1828 MILACRES
TOTAL OVER 15,000 MILACRES
1·8
1·6
1·4
1·2
1·0
0·8
0·6
0·4
0·2
DENSITY (d)
OMITTED BY BEVER (300 MILACRES)
h=3
BEVER'S OWN CURVE
RANDOM h=1
MINIMUM (h=0)
FREQUENCY (f)
10%
20%
30%
40%
50%
60%


GRAPH 2
BEVER'S DATA RE-EXAMINED
- EACH POINT = 160 MILACRES (TOTAL OVER 15,000 MILACRES)
"CORRELATION CURVE" IS THE MEAN OF THE TWO REGRESSION CURVES d on f AND f on d /.
DENSITY (d)
FREQUENCY (f)
1·8
1·6
1·4
1·2
1·0
0·8
0·6
0·4
0·2
10%
20%
30%
40%
50%
60%
2.19
"CORRELATION CURVE"
BEVER & LAVENDER - 1955
(INCLUDES SOME EXTRA DATA)
BEVER - 1949
BEVER
RANDOM DISTRIBUTION
MINIMUM DISTRIBUTION

Whenever a distribution of small individuals is sampled by quadrats, the first individual on each quadrat affects both "do" and "f". All subsequent individuals affect only the density "do".

The line dm = f/100 is the line that is produced if every stocked quadrat contained only one individual. Because of this it is impossible for data to occur below this line.

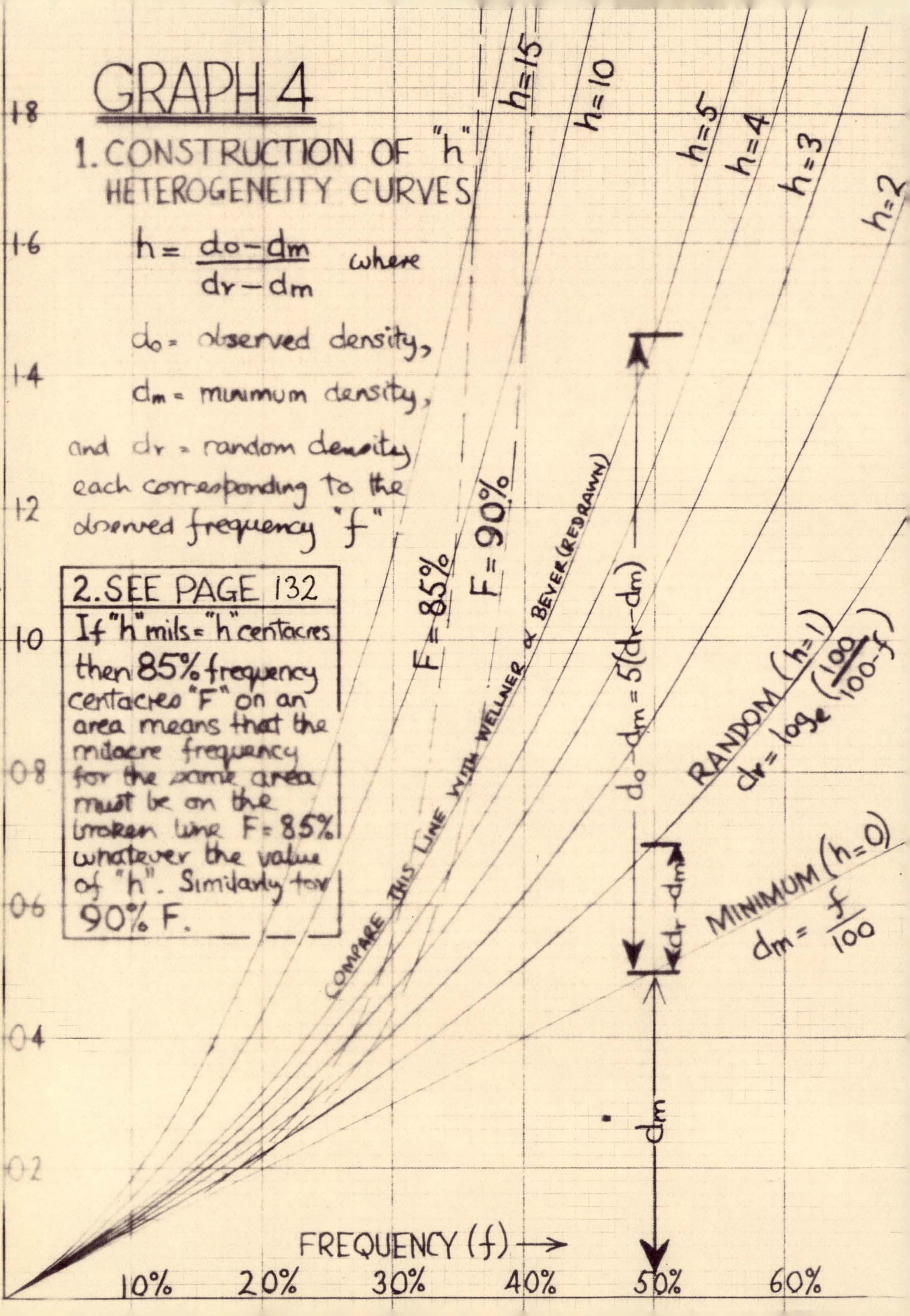
Any mathematical relationship that exists between "do" and "dr" is likely to have the line dm = f/100 as one axis instead of the abscissa.

The only curve in Graph 1 that fails to "nest" with the others is that produced by Bever (1949). In Graph 2 the data of Bever (1949), and Bever & Lavender (1955) are re-examined. Bever (1949) drew a curve based on the regression of density on frequency and Bever and Lavender apparently use the same technique for extended data. However both frequency and density are subject to error and chance and the relationship between them should be one of correlation and not a regression of one against another. The "correlation curve" in Graph 2 is the mean of the two regression curves frequency-on-density and density-on-frequency. This curve fits very neatly into the others on Graph 1, practically following Wellner's (1940) data. One further fault with Bever & Lavender's curve is that it fails to pass through the origin. If there is no frequency there can be no density and vice versa. (Ker (1953) also ignores this obligatory point in his logarithmic straight line relating frequency to density.)

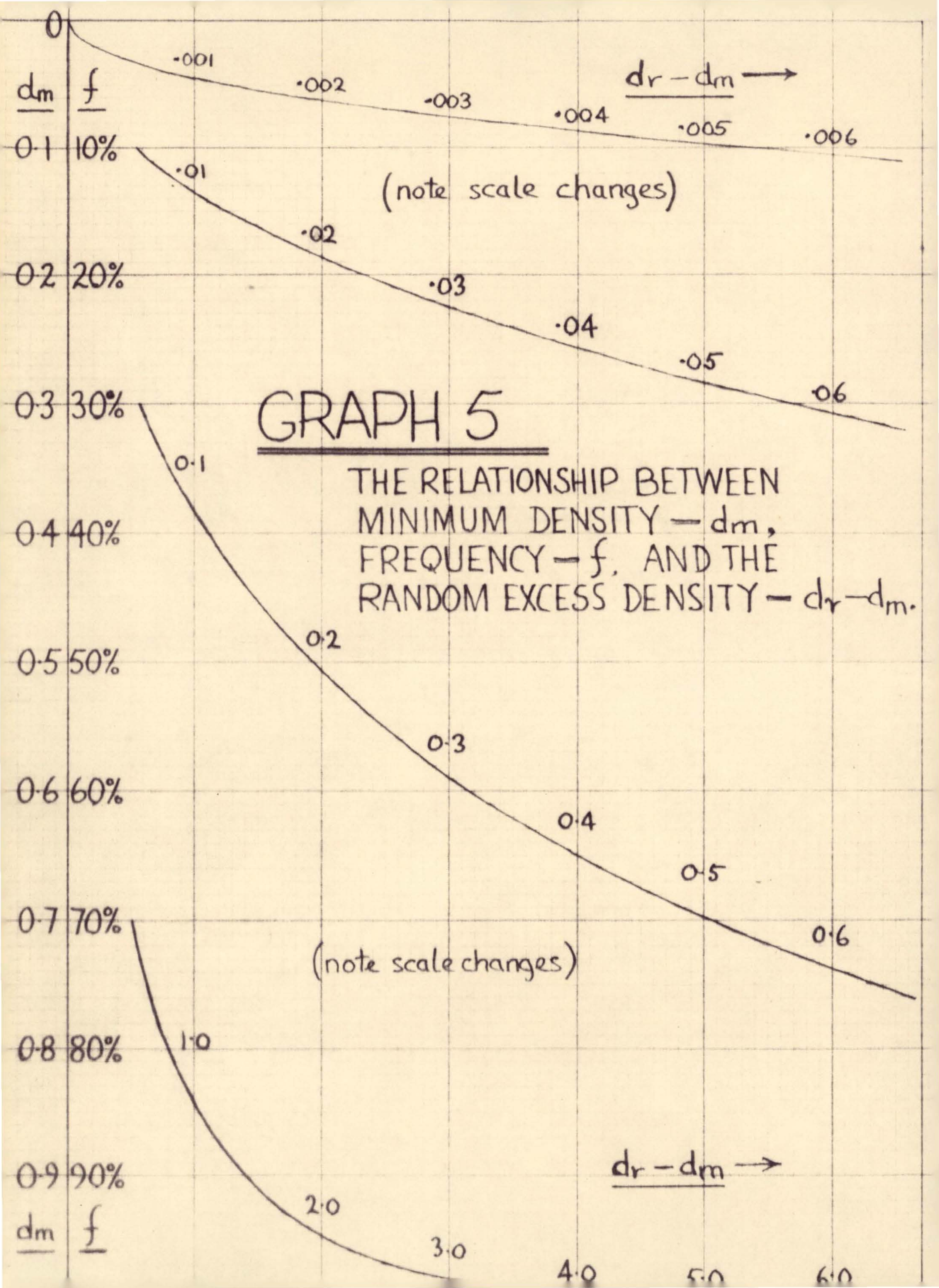
Graph 3 re-examines Bever's (1952) data for artificial sowings. If the point omitted by Bever is allowed, it can be seen that the constructed curve h=3 (see later) is a better fit to the data for all but the frequency range 15-20%.

Using the amended data from Graphs 2 and 3 it appears that all the given data are asymptotic to the line dm = f/100, to the random curve, and to each other.

Because of this "nesting" of observed data from different sources with the Poisson curve, and because all data was



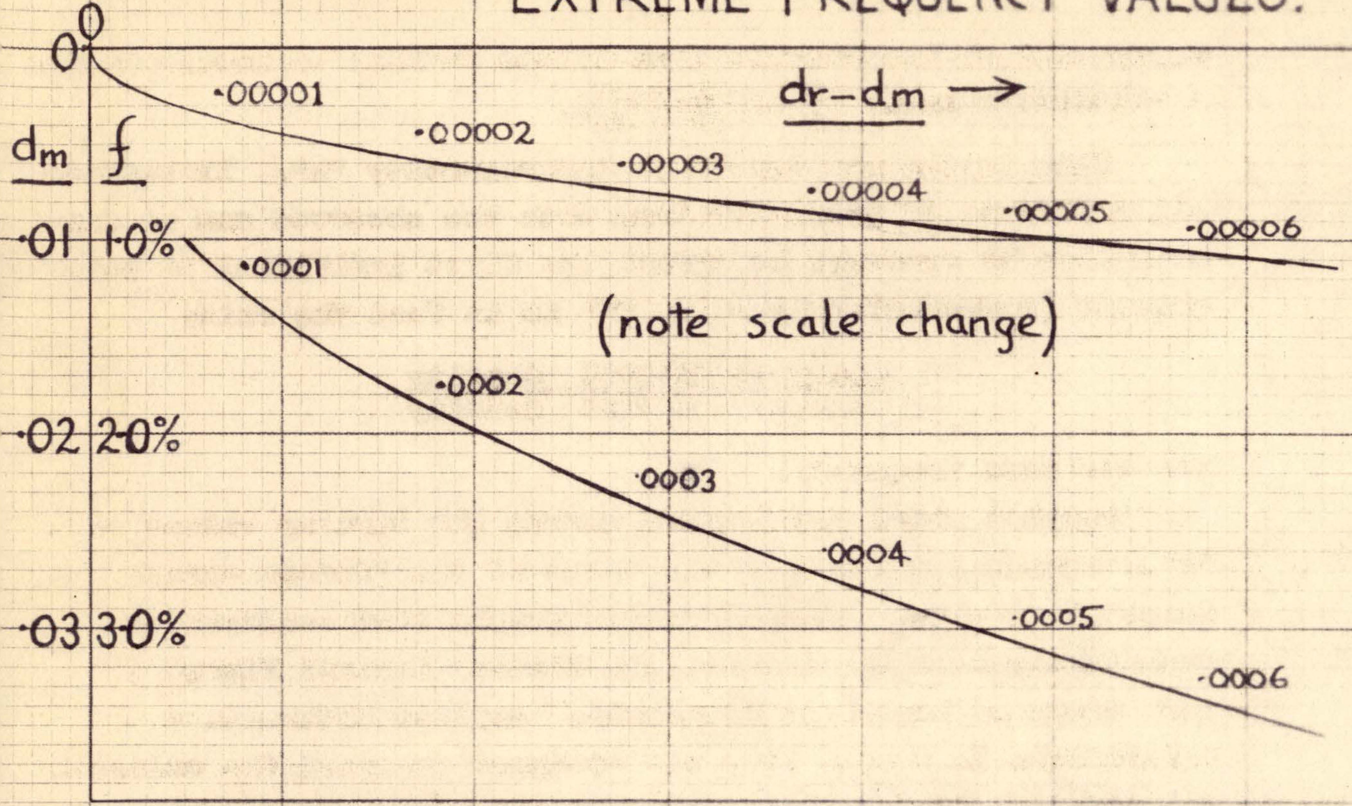
GRAPH 4
1. CONSTRUCTION OF "h" HETEROGENEITY CURVES
$h = \frac{do - dm}{dr - dm}$ where
do = observed density,
dm = minimum density,
and dr = random density
each corresponding to the observed frequency "f"
2. SEE PAGE 132
If "h" mils = "h" centacres then 85% frequency centacres "F" on an area means that the milacre frequency for the same area must be on the broken line F = 85% whatever the value of "h". Similarly for 90% F.
h=15
h=10
h=5
h=4
h=3
h=2
F = 85%
F = 90%
COMPARE THIS LINE WITH WELLNER & BEYER (REDRAWN)
$do - dm = 5(dr - dm)$
RANDOM (h=1)
$dr = \log_e \left(\frac{100}{100-f}\right)$
MINIMUM (h=0)
$dm = \frac{f}{100}$
$dr - dm$
dm
DENSITY (d) →
FREQUENCY (f) →
1·8
1·6
1·4
1·2
1·0
0·8
0·6
0·4
0·2
10%
20%
30%
40%
50%
60%

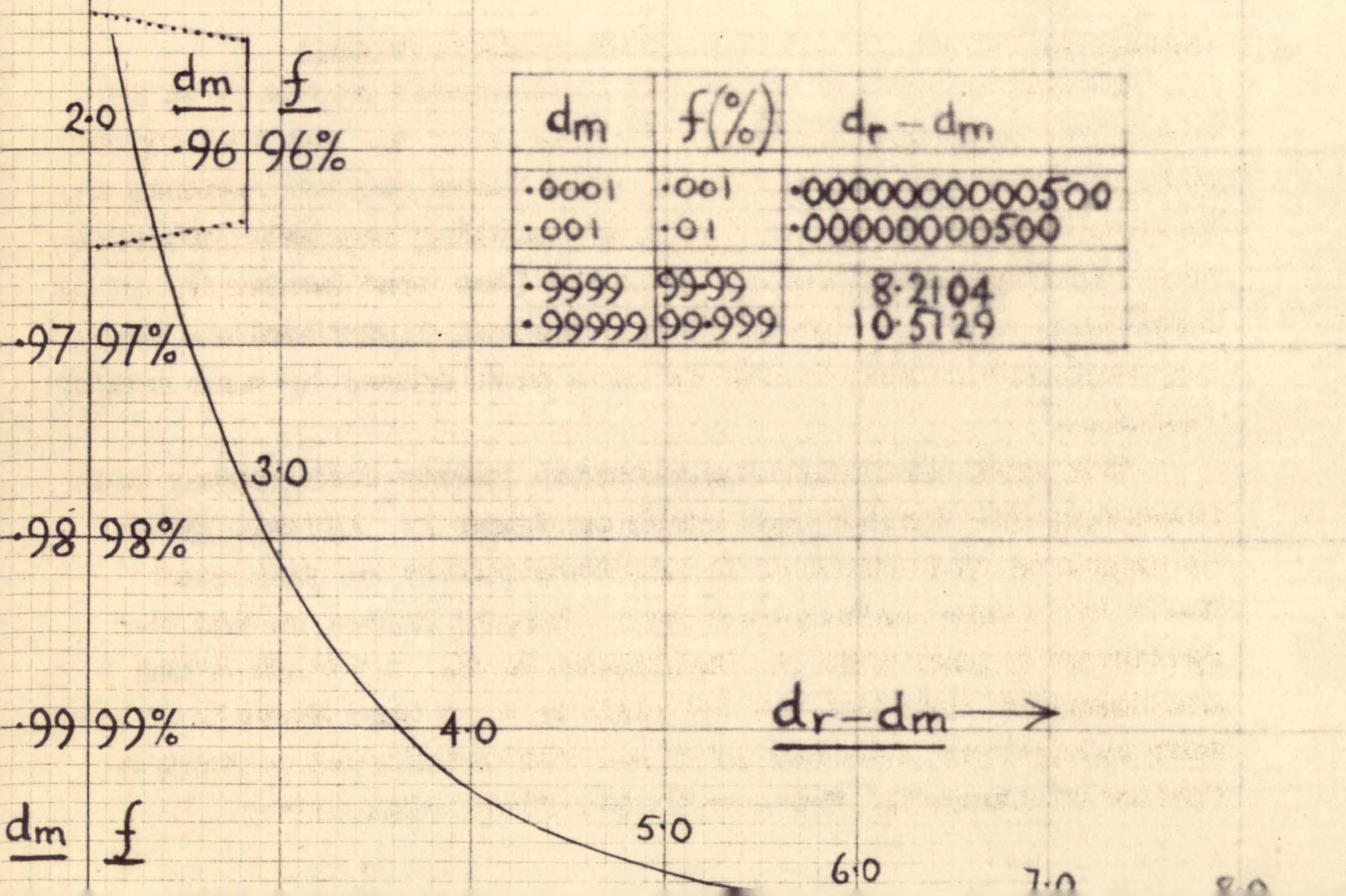


GRAPH 5

THE RELATIONSHIP BETWEEN MINIMUM DENSITY — d_m, FREQUENCY — f, AND THE RANDOM EXCESS DENSITY — $d_r - d_m$.

GRAPH 6 PART OF GRAPH 5 REDRAWN FOR EXTREME FREQUENCY VALUES.





d_m	f (%)	$d_r - d_m$
·0001	·001	·000000000500
·001	·01	·0000000500
·9999	99·99	8·2104
·99999	99·999	10·5129

asymptotic to the minimum line it was decided to modify Gill's & Whitford's ratio $\frac{do}{dr}$ to $\frac{do - dm}{dr - dm}$.

This is the new factor of heterogeneity "h". It removes all influence of frequency from both the observed and random densities by removing in effect the first individual on each quadrat (represented by dm). "h" is in fact the ratio

$$\frac{\text{observed EXCESS density}}{\text{random EXCESS density}}$$

for the same frequency.

Graph 4 shows the derived curves for various values of "h". Graphs 5 and 6 show the value of the "random excess density" dr - dm. These last two graphs were constructed from "...Natural Logarithms...to Sixteen Decimal Places". U.S. National Bureau of Standards. Applied Mathematics Series Nos. 31 & 53. They are designed to speed the calculation of "h" from observed data for the rapid construction of "h" curves.

The Constancy of "h" over a Range of Frequencies

In any one distribution of individuals on one area at one time there must be only one frequency and one density for each quadrat size. This means that there are two methods of testing the constancy of "h" - by sampling the same distribution with various sizes of quadrats (see next heading), or by sampling, with one quadrat size, several distributions whose heterogeneities are likely to have been caused by some common factors.

The most important regeneration survey data giving both frequency and density are shown on Graph 1. If this graph is compared with Graph 4 it can immediately be seen that Wellner's curve corresponds very closely indeed to and "h" factor of 5, and that of Cunningham to 7. If Graph 2 and 3 are compared with Graph 4 it will be seen that Bever's naturally sown areas have a factor of 5 and his artificial sowings a factor of about 3. However in the Florentine surveys the

the heterogeneity rises from about 10 to about 15 as the frequency increases from 0 to 40%. This increase of "h" with frequency is probably due to the lumping of results obtained from surveys of unburnt, unregenerated areas with dense patches of regeneration found on good burns. This effect of seedbed on "h" will be discussed in more detail later.

Other data which supports the theory of constancy of "h" over a range of frequencies in this way are as follows:-

(i) Florentine Expt 13D

	f	d	h
(a)	35.3	0.9	6.7
(b)	60.0	2.7	6.6

(a) is well burnt seedbed, (b) is disturbed seedbed on tracks passing through (a) under the same seed trees and both seeded following the same fire.

This example is not very important because the sample was so small but it is the only information yet obtained giving two frequencies with the same quadrat size under nearly identical conditions of seed distribution.

(ii) Bever (1949)

Bever used both milacre and 4-milacre quadrats in his assessment of naturally seeded areas. If his 4-milacre curve is re-drawn (c.f. Graph 2) as a "correlation curve" it is again very close to the constructed curve h=5 for all frequencies.

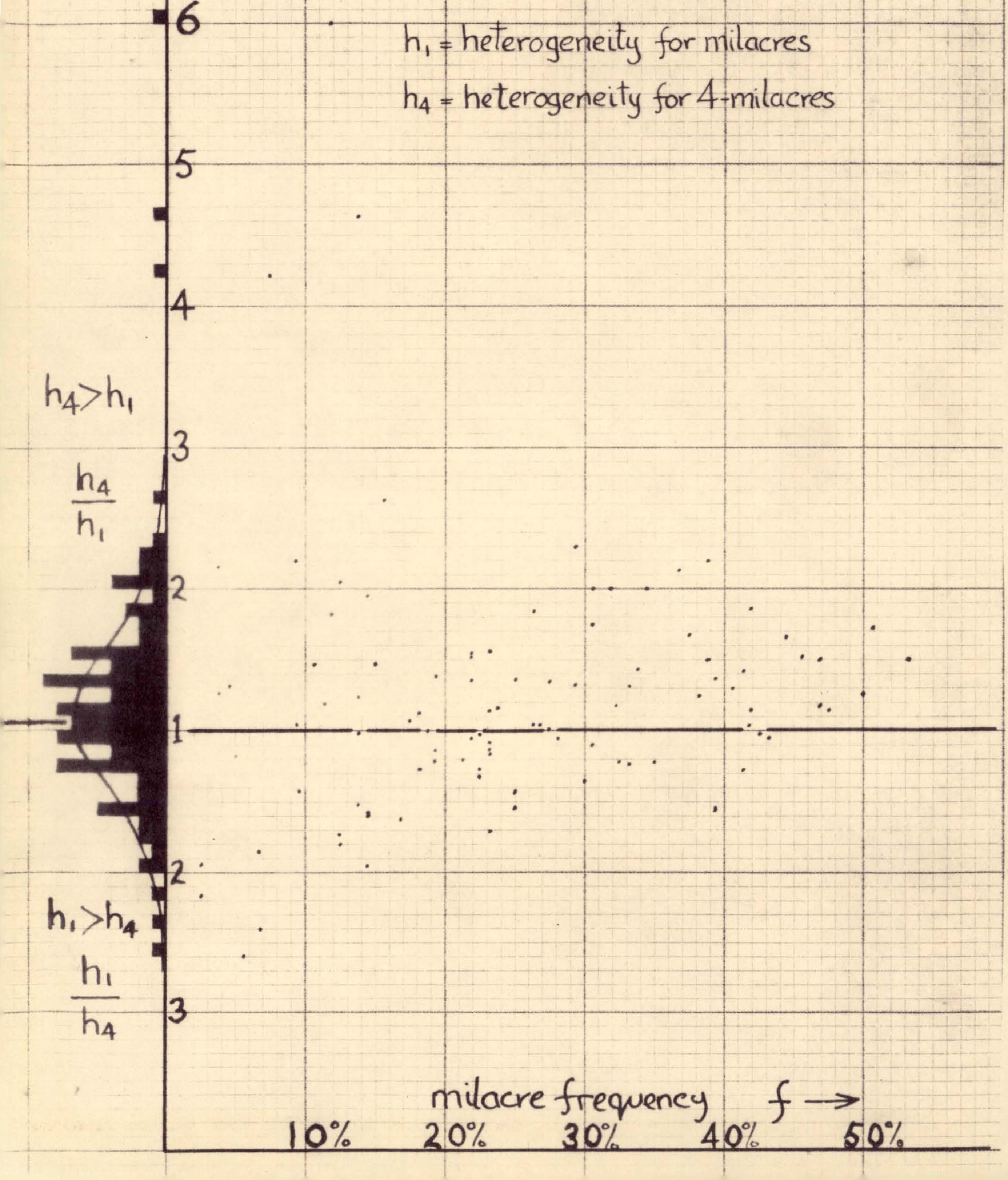
(iii) Wellner (1940)

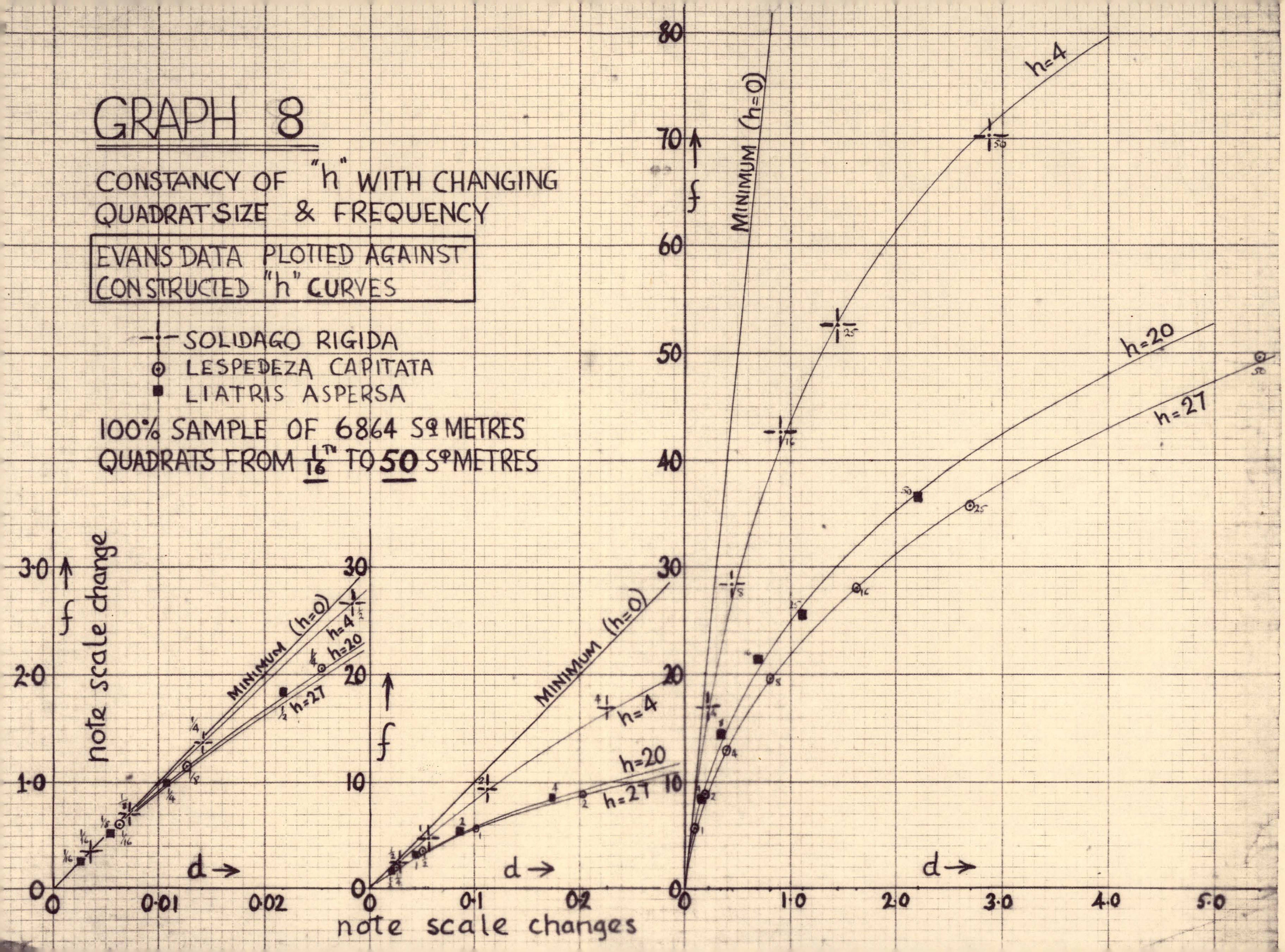
Wellner also used 4-milacre quadrats and drew a curve very close to h=8 for all frequencies. The fact that Wellner's milacre data gave h=5 will be discussed later.

Curves that show a marked divergence of "h" with frequency were constructed by Gill (1950) and Ker (1953) but their data (as opposed to their curves) is at least equally well served by constructed curves of constant "h". Parker &

GRAPH 7

THE RELATIONSHIP BETWEEN "h_1" & "h_4" FROM BEVER'S DATA




GRAPH 8
CONSTANCY OF "h" WITH CHANGING QUADRAT SIZE & FREQUENCY
EVANS DATA PLOTTED AGAINST CONSTRUCTED "h" CURVES
SOLIDAGO RIGIDA
LESPEDEZA CAPITATA
LIATRIS ASPERSA
100% SAMPLE OF 6864 Sq METRES
QUADRATS FROM 1/16th TO 50 Sq METRES
MINIMUM (h=0)
h=4
h=20
h=27
f
d
note scale change
note scale changes
0
0.01
0.02
0.1
0.2
1.0
2.0
3.0
4.0
5.0
10
20
30
40
50
60
70
80

Potter (1951) and Allen, Griffith & Ker (1951) produced curves of 19-25 year old regrowth which generally follow values of "h" close to random. However at higher frequencies "h" tended to decrease slightly due to these authors purposely disregarding seedlings in excess of 11 on any one quadrat.

No evidence of the weight of Bever's or that of Evans (1952) has been found that disagrees with the hypothesis of constancy of "h" over a range of frequencies. Except where the effect of seedbed heterogeneity has a marked effect (see later).

The constancy of "h" with a Range of Quadrat Sizes

The relationship between the values of "h" derived from Bever's two quadrat sizes is shown in Graph 7. It can be seen that there is a nearly symmetrical distribution about unity. The slight tail favouring high values of h_4 is believed to be due to the fact that each point represents 160 milacres but only 40 4-milacres. The very slight trend favouring higher h_4 values at the higher stockings would probably disappear if there could be equal numbers of each quadrat size.

Bever's data suggests that with a reasonable number of quadrats the "h" derived from milacres is of the same order as that derived from a quadrat four times as large.

Graph 8 shows that the remarkably close fit of constructed "h" curves with data from Evans (1952) - quadrat sizes 1/16 to 16 square metres, and Cain and Evans (1952) - quadrat sizes 25 to 50 square metres. These two sources cover the same experiment and they represent by far the best support for the hypothesis of constancy of "h" with changes in both frequency and quadrat size. This is especially true for the higher values of "h".

Wellner's data does not support constancy of "h" between milacres and 4-milacres. His curves give h=5 and h=8 respectively. This is almost certainly due to his survey method. Wellner counted seedlings on milacre quadrats one chain apart.

He also sub-divided each chain into five 4-milacre quadrats which he inspected for frequency only. This means that for the larger quadrats "do" was derived from 1/20th of the area that "f" was derived from. From personal experience I find it impossible to believe that the five 4-milacres were inspected as closely as the one milacre at the end of each chain. It is likely that he missed seeing seedlings on about 10% of the larger quadrats that were actually stocked. If such a correction were applied to Wellner's data, a constant "h" of 5 would then apply to both his milacre and his 4-milacre data.

The data provided by Bever, Evans and Cain & Evans is extensive and it strongly supports the hypothesis of constancy of "h" over a range of quadrat sizes, at least from 1/16th to 50 sq metres. For this reason I feel justified in giving little weight to the apparently contrary part of Wellner's evidence.

Further support for the hypothesis of constancy of "h" for a range of quadrat sizes comes from leaf-gall data presented by Waters & Henson (1959). These authors suggested that there appeared to be a lack of "valid and meaningful measures of aggregation" which could simplify their work. They counted every leaf-gall on 18 trees and their results are summarised below:-

	TOTAL QUADS	f	d	h
Single leaf	52,504	8.6%	0.21	32.3
Single leaf bunch	12,270	19.0%	0.88	33.3
2-leaf bunches	6,529	26.9%	1.65	31.9
5-leaf bunches	2,851	41.9%	3.78	27.1
Branch	757	57.5%	14.29	48.8

The table shows a relatively constant "h" between the first four sample sizes which in fact vary in size from

1 leaf to 5.

There is a marked increase in "h" when the sample size is increased to include the whole branch which would have been a sample size of an average of 70 leaves. It would appear that in this case "h" has remained constant over quite a wide range in sample size but not one of the order of 70 times the smallest. It is also possible that the necessarily wide variation in actual sample size (number of leaves per branch) within this class rather than the size of the sample itself has contributed to the high value of "h".

Although it is considered that most of the evidence available supports the contention that "h" is constant over a range of quad sizes it must vary if the quadrat size is extremely small. If the quadrat is only a little larger than the individual then "do" must be close to "dm" and "h" read close to zero however clumped the individuals actually are. This does not mean that "h" cannot be measured at very low frequencies. As long as the quadrat size is considerably larger than the individual an estimate of "h" can be given as soon as more than one individual is found within one quadrat. Obviously, accurate measures of "h" at very low frequencies are likely to require rather more quadrats than usual.

At the other extreme as soon as the frequency reaches 100% "h" is again un-measurable. However troubles at both extremes can generally be avoided by adjustment of the quadrat size.

Stocking Standards

The idea of basing stocking standards on the acceptable number of 1/100th acre gaps is fully discussed in the APPITA paper (in Appendix).

Where "h" is found to be constant for a range in quadrat sizes from centacres to milacres it is possible to derive stocking standards based on centacres stocking but measured in milacre stocking.

On Graph 4 are two dotted lines representing "centacre" frequencies F=85% and F=90%. These lines are drawn on the assumption that "h" is constant for the range of milacres to centacres. These lines were constructed as follows:-

If F=90% and h=5 and D=h(Dr-Dm) + Dm

Dr-Dm for F=90% can be read from Graph 5, Dm=0.9

Hence D=5(1.4) + 0.9 = 7.9

But D the density on 1/100th acre quadrats must equal ten times "d" the density on milacre quadrats. Therefore "d"=0.79.

Using the same "h" and this derived "d" Graph 4 indicates that "f" equals about 36%.

The really interesting point is the high proportion of values in the frequency range 30% to 40%. This suggests that it is not just chance that caused practically all authors to put their recommended minimum stocking standard within this range e.g.

Milacre Frequencies Corresponding to Centacre Frequencies of 85 and 90%

"h" = F 85%

1	2	3	4	5	6	7	8	9	10	15	20	25
17.3	23.1	26.8	29.2	30.8	32.0	32.9	33.6	34.2	34.7	36.0	36.7	37.2

"h" = F 90%

1	2	3	4	5	6	7	8	9	10	15	20	25
20.7	27.7	31.9	34.3	36.0	37.2	38.1	38.8	39.3	39.7	41.1	41.7	42.2

The only authors to propose stocking standards outside the range 30-40% milacres are those who work back from a theoretical standard of say 750 seedlings per acre and who also sampled 20 year old stands with a near random stocking (e.g. Allen, Griffith & Ker 1951). In such cases 750 seedlings requires an "f" about 50%. Such findings were never made by workers who sampled young regeneration.

<u>The Effect of Variations of Seedbed on "h"</u>

Some species apparently regenerate on a great range of micro-sites while others are much more selective. The ash type eucalypts fall into the second group. E.regnans germinations are most successful on lightly disturbed soils near the edges of tracks and on well burnt areas providing also that they are not shaded. Germination occurs in shaded areas but the seedlings do not live for long (Gilbert 1958). Successful regeneration seldom occurs on unburnt seedbeds and is very tardy on compacted tracks.

The 1084 milacre of the S2 part of this intensive survey were separated into three sites with three "borders" and the regeneration (in terms of numbers/acre) recorded as follows:-

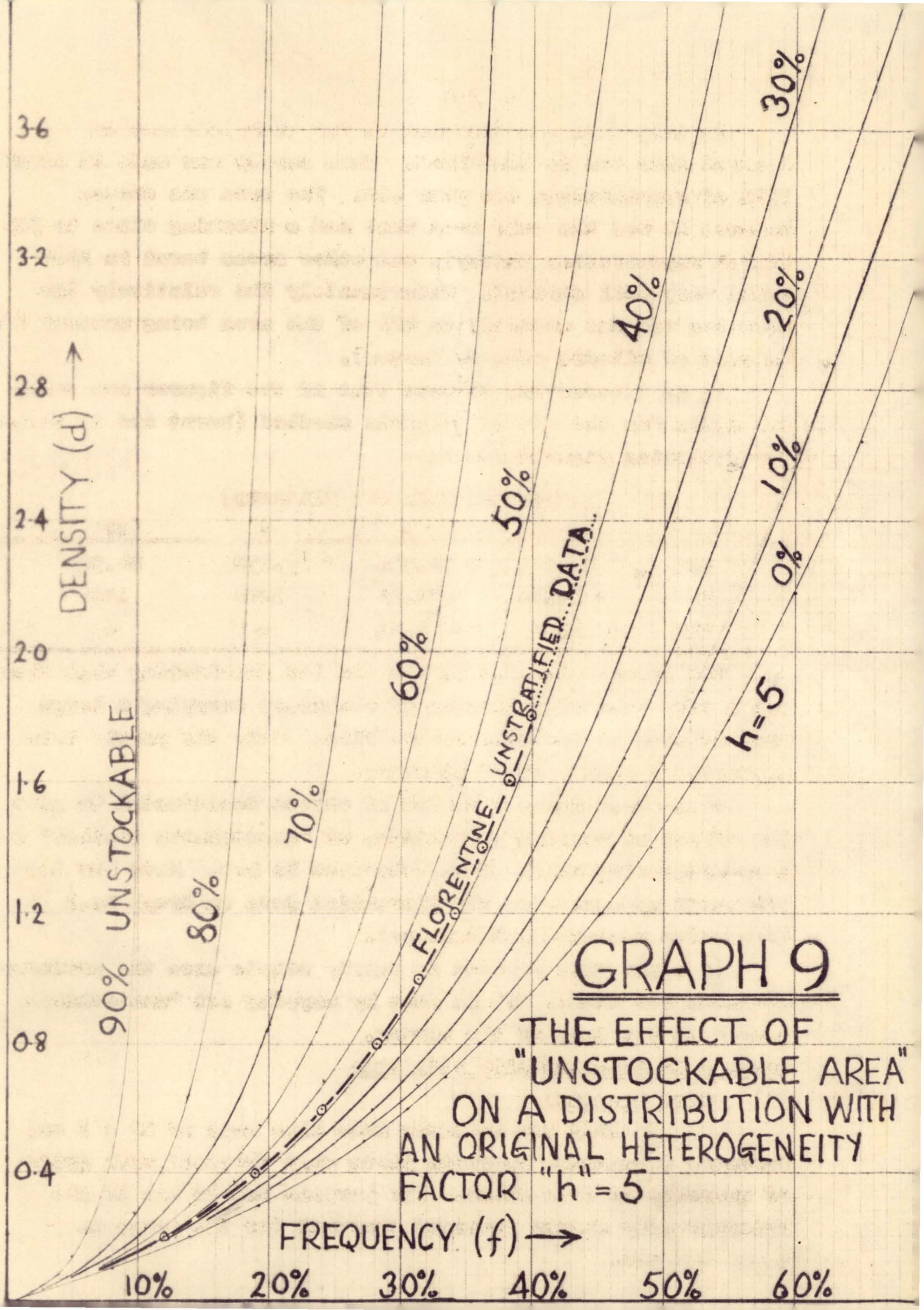
TOTAL Quadrats		"f"	Seedlings/acre	
Disturbed	181	34.9	917)	
Burnt/Disturbed	57	42.2	1474)	Stocked
Burnt	514	25.2	494)	
Burnt/Unburnt	44	6.8	68)	Under-
Unburnt	250	2.4	24)	Stocked
Unburnt/Disturbed	38	7.9	79)	
TOTAL	1084	21.2	476	

Because of the specific seedbed preference the distribution of seedlings can be affected to a great degree by the distribution of the various types of seedbed available. A theoretical example is given on page 81 of the APPITA paper.

Florentine Experimental Survey

Before leaving the Florentine area in June 1961 an experimental survey was made to test the theory of constancy of heterogeneity for the range of quadrat sizes one milacre to one centacre. The results of the survey were disappointing because of the patchiness of the burn combined with a heavy seed fall. In all 278 plots were examined each containing 4 concentric circular quadrats.

Quadrat Size (Milacres)	1	2	4	10
Density "d"	1.424	2.828	5.676	14.240
Frequency "f"	44.3	53.3	59.0	67.3
Heterogeneity "h"	6.9	11.0	17.0	30.6



GRAPH 9

THE EFFECT OF "UNSTOCKABLE AREA" ON A DISTRIBUTION WITH AN ORIGINAL HETEROGENEITY FACTOR "h" = 5

In this data the increase in "h" with increase in quadrat size can be explained. This survey was made in March 1961 of regeneration one year old. The area was chosen because it was the only area that had a stocking close to 30% (A.N.M regeneration survey), all other areas burnt in 1960 being very well stocked. Unfortunately the relatively low stocking was due entirely to 42% of the area being unburnt (in patches of milacre size or larger).

It is interesting to note that if the figures are taken out again for the 58% of suitable seedbed (burnt and disturbed) the following figures result:-

	QUADRAT SIZE (IN MILACRES)			
	1	2	4	10
"d"	2.4358	4.916	9.832	24.58
"f"	76.4%	91.6%	100%	100%
"h"	2.49	2.51	-	-

The figure of h=2.5 is not too low considering that there was a very even distribution of seedtrees carrying a large crop of seed at the time of the fire. Only the patchy burn prevented a high overall stocking.

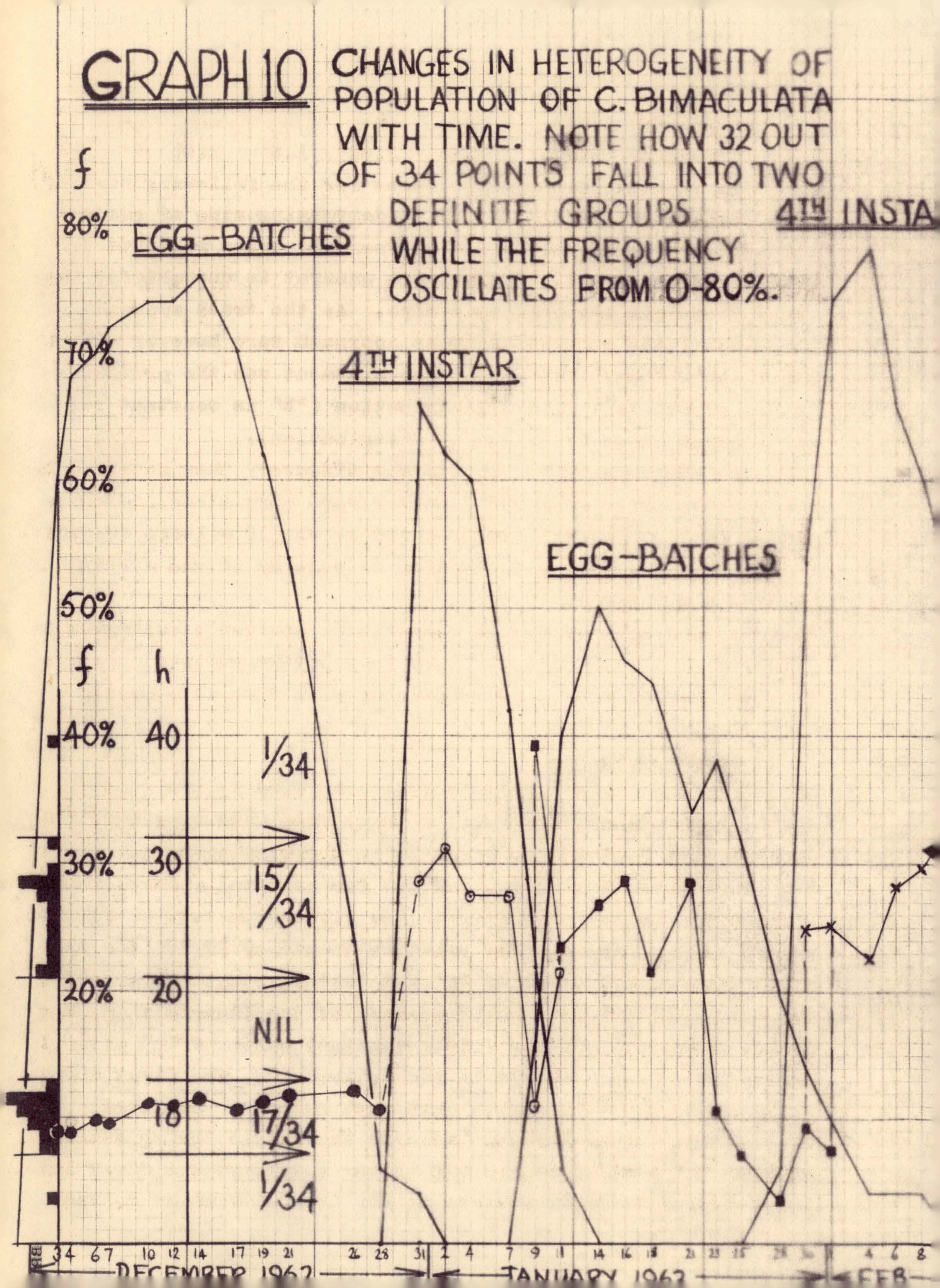
Graph No.9 shows a series of curves constructed to give the effect of varying percentages of "unstockable seedbed" on a heterogeneity which would otherwise be h=5. Note how the 40% curve approximates the Florentine data on Graph No.1 (Extensive unstratified surveys).

To avoid this problem is fairly simple once the prefered seedbeds are known. It is done by mapping out "unstockable areas" at the time of the survey.

<u>Changes in Heterogeneity with Time</u>

(i) <u>Slow Changes:</u>

In 1963 the existing stem plan maps of 20 x 1 ac. Forestry Commission regrowth plots were overlaid with grids of quadrats of four sizes. The purpose was to see if the heterogeneity factor remained constant for the range in quadrat sizes.


GRAPH 10
CHANGES IN HETEROGENEITY OF POPULATION OF C. BIMACULATA WITH TIME. NOTE HOW 32 OUT OF 34 POINTS FALL INTO TWO DEFINITE GROUPS WHILE THE FREQUENCY OSCILLATES FROM 0-80%.
f
80%
70%
60%
50%
EGG-BATCHES
4TH INSTAR
EGG-BATCHES
4TH INSTA
f
h
40%
40
30%
30
20%
20
18
1/34
15/34
NIL
17/34
1/34
3 4 6 7 10 12 14 17 19 21 26 28 31
2 4 7 9 11 14 16 18 21 23 25 28 30
1 4 6 8
DECEMBER 1962
JANUARY 1963
FEB

Quadrat Size	1	4	8	16
Heterogeneity	1.36	1.61	1.64	1.84

The results were disappointing for the following reasons. The decreasing heterogeneity with decreasing size of quadrat was caused by the size of the 40 year old trees relative to the smaller quadrats. The milacre quadrat is undoubtedly too small to sample trees of this size. As the trees approach the size of the quadrat "h" must approach zero however clumped the distribution. The next disappointment was the proximity of the growth to a random distribution ("h" is constant for all quadrat sizes for a random distribution).

One encouraging result was the discovery that in all sub-samples the trees over 10" diameter were very close indeed to random in distribution (as measured by the 16 milacre quadrats). This suggests that the assumption on page 80 of the APPITA paper was a valid one.

In time this effect of competition between seedlings will probably make most distributions less heterogeneous. However this sort of change in heterogeneity with time is probably very slow.

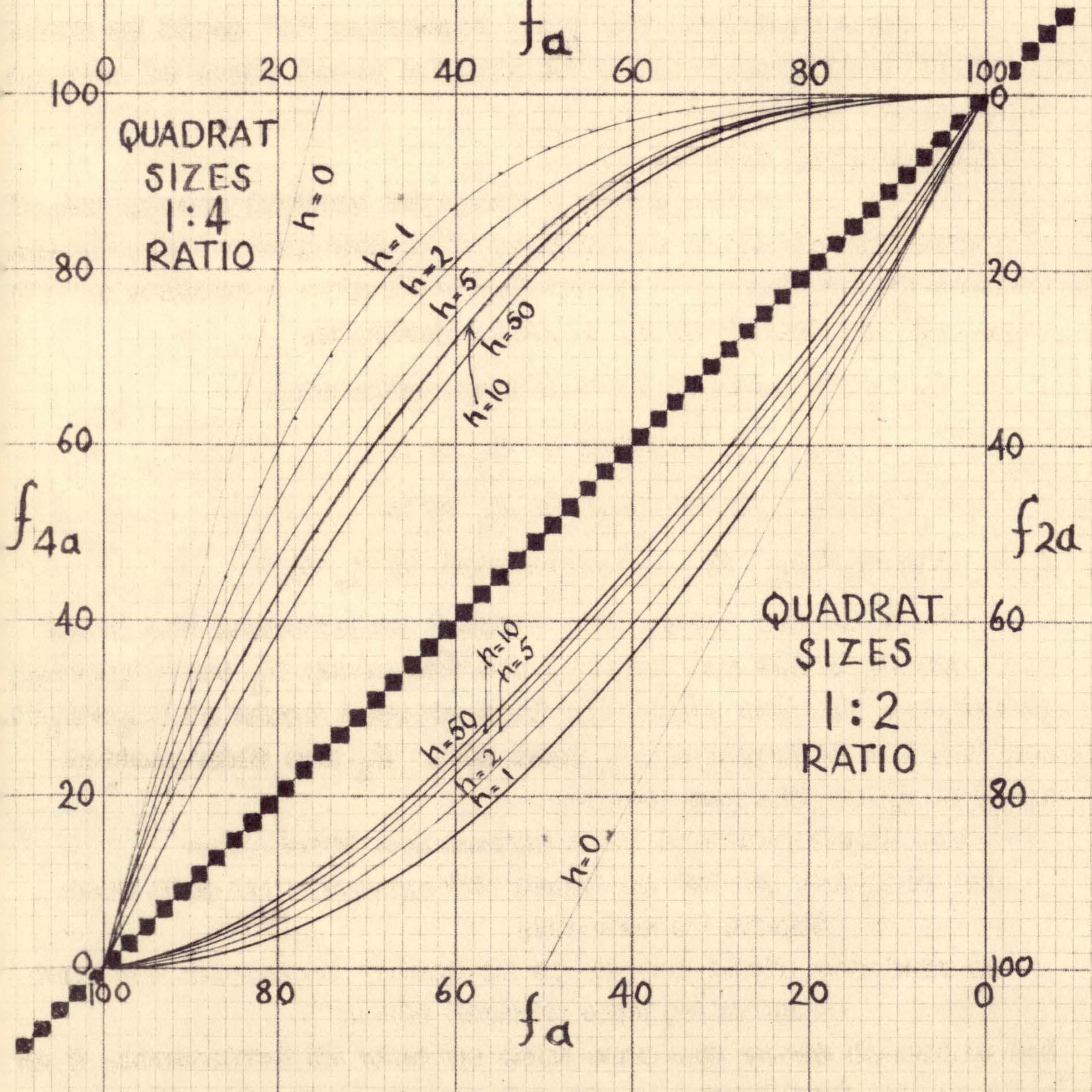
(ii) Sudden Changes:

Much more sudden changes are found in the study of insect populations. Graph 10 is drawn from data supplied by R. Greaves from 1962-63 observations of Chrysoptharta bimaculata. The graph shows "do", "f", and "h" for repeated observations, on quadrats which are branches of a given diameter, of various stages of the insect. The relative constancy of "h" for the first four weeks, in which "f" and "do" fluctuate so greatly, suggests that "h" is a valid measure of the distribution. The sudden change to another fairly constant value of "h" probably indicates a sudden change in the environment. The first change is probably due mainly to the fact that each egg-batch produced several 4th instar larvae. However the second laying starts with an "h" similar to the 4th instar larvae of the first laying but then suddenly reverts to the low "h" similar to the first laying.

GRAPH 11

THE RELATIONSHIP BETWEEN FREQUENCIES OBTAINED FROM QUADRATS OF TWO SIZES

f_a = frequency with quadrats of area "a"
f_{2a} = " " " " "2a"
f_{4a} = " " " " "4a"



It is postulated that this sort of analysis of insect data could lead to the isolation of the factors that have the greatest influence on populations which the relatively violent fluctuations of frequency and density tend to obscure.

Possible Short Cuts to the Determination of "h".

If frequency is measured and "h" is known density can be calculated. So far it has only been possible to calculate "h" accurately from measuring both "f" and "do". In other words "h" does not simplify the measurment of the distribution but rather classify it.

If some reliable method of measuring "h" could be devised it might still be possible to avoid a total count of individuals on all quadrats.

a) Two Quadrat Sizes

If "h" is constant for a range in quadrat sizes, and if the same distribution is sampled with two quadrat sizes, then comparison of the two frequencies will give a measure of "h":-

e.g. f_1 = frequency by milacre quadrats.

f_4 = frequency by 4-milacre quadrats.

f_1 is related to d_1 by h

f_4 is related to d_4 by h

But $d_4 = 4d_1$ $\therefore$ f_1 is related to f_4 by h

Graph 11 was drawn from Graph 4 be entering the graph with say $d_1 = 1.0$ and reading the frequency f_1 corresponding to say h = 5. The graph was then entered again at $4d_4 = 4d_1 = 4.0$ and the h = 5 frequency f_4 read off. f_1 was then plotted against f_4 on the new graph.

The limitations of this method are two-fold:-

for accuracy of "h" at least 100 quadrats of each size should be sampled;

to minimise field errors it is better to sample the same area with each quadrat size.

100 milacres cover the same area as only 25 4-milacres, $\frac{3}{4}$ of each of 100 4-milacres would get rather less attention in

the field than the ¼ also sampled to obtain 100 milacres.

It may be reasonable to have, say, 50 4-milacres with all milacres assessed and then compare the milacre frequency with the mean of two sets of 2-milacre frequencies.

e.g. 4 quarters of a circular 4-milacre quadrat are a, b, c, d. 2 milacre pairs could be ab & cd, or ad & bc.

This method was tested against data from the Tyenna Valley regeneration surveys of 1955 where 8' radius quadrats were used and where all seedlings were mapped onto a quartered diagram.

	8' Radius	a,b,c,d	ab, cd	ad, bc	Mean ½ plot
"f"	77.8	40.7	56.5	60.2	58.3
"d"	3.595	0.899	1.797	1.797	1.797
"h"	3/94	4.24	4.52	3.77	4.19
(No of quadrats)	(54)	(216)	(108)	(108)	(108)

Suppose no seedlings had been counted but only their presence or absence noted on each quarter of the 8' radius quadrat three frequencies for three quadrat sizes could be calculated.

f_4 (8' radius)	77.8%	(54 quadrats)
f_1 (quarter)	40.7%	(216 quadrats)
f_2 (half)	58.3%	(2x108 quadrats .. mean of two combinations of the same data)

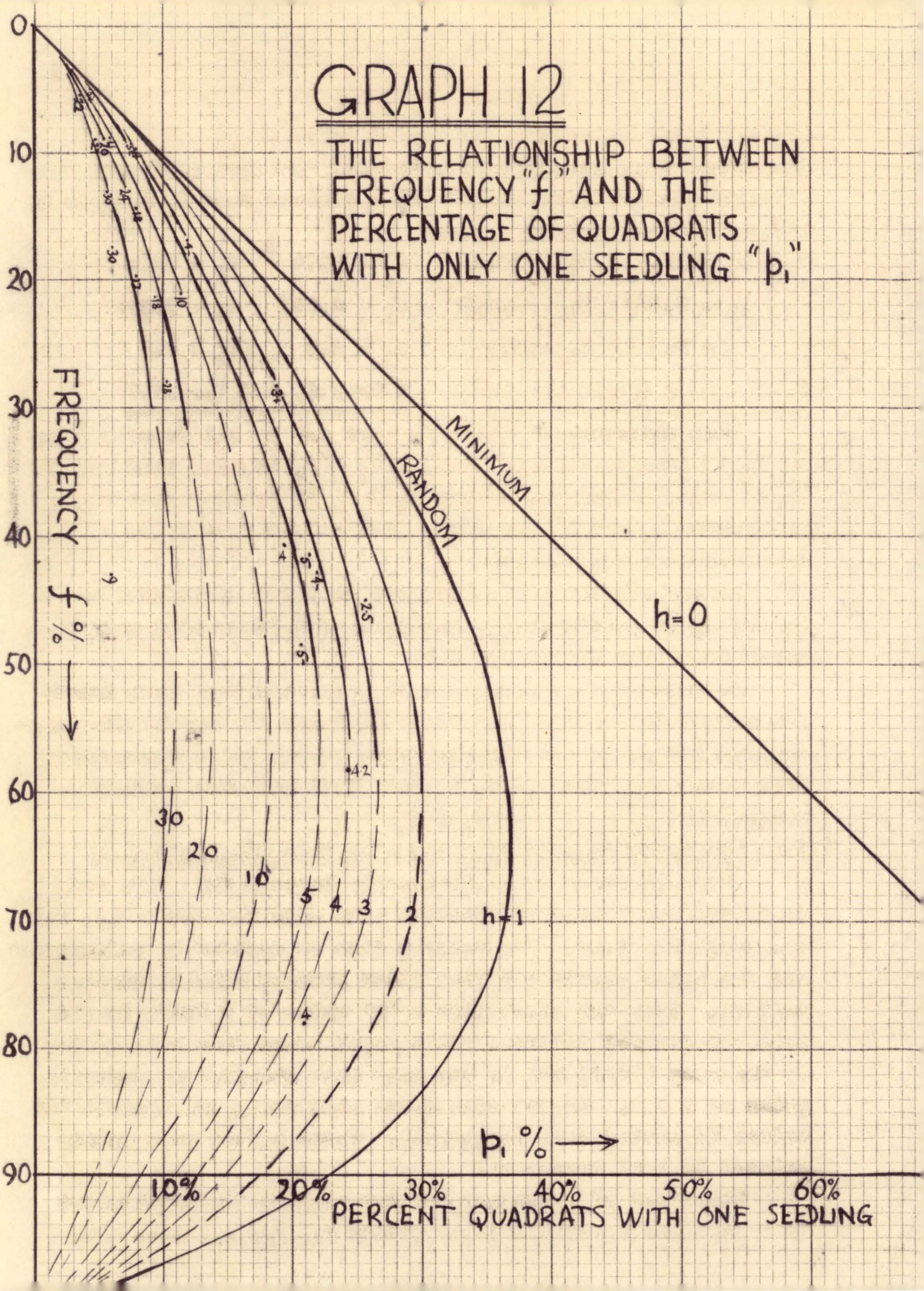
These frequencies can be entered on Graph 11 in pairs and the approximate heterogeneity read off:-

f_1 & f_4 .... h approximately 4

f_2 & f_4 .... h " 3

f_1 & f_2 .... h " 4

The pitfalls of this method are illustrated from Bevor's


GRAPH 12
THE RELATIONSHIP BETWEEN FREQUENCY "f" AND THE PERCENTAGE OF QUADRATS WITH ONLY ONE SEEDLING "p1"
MINIMUM
RANDOM
h=0
h=1
30
20
10
5
4
3
2
FREQUENCY f %
p1 %
10%
20%
30%
40%
50%
60%
PERCENT QUADRATS WITH ONE SEEDLING
0
10
20
30
40
50
60
70
80
90

(1949) data. This data was tested against Graph 11 and it was found that any difference between "h" (derived from f & d) between quadrat sizes caused the h derived from f_1 & f_4 to be outside both estimates e.g.

$f_1 = 38.8$	$f_4 = 70.0$	$f_1 = 39.4$	$f_4 = 82.5$
$d_1 = 0.669$	$d_4 = 2.652$	$d_1 = 0.800$	$d_4 = 3.200$
$h_1 = 2.6$	$h_4 = 3.9$	$h_1 = 3.9$	$h_4 = 2.5$
h from f_1 & f_4 approx: 10		h from f_1 & f_4 ....1.6	

This unfortunate effect is born out by all Dover's data; if h_1 is greater than h_4, h from f_1 & f_4 is less than both. If h_4 is greater than h_1, h from f_1 & f_4 is greater then both. Only where h_1 and h_4 are close will h from f_1 & f_4 be a reasonable approximation.

It has already been suggested that the difference between h_1 and h_4 is partly due to the fact that Dover used only 40 quadrats of the 4-milacre size.

Because of this hazard it is important that this short-cut method be employed only with adequate numbers of the larger quadrat size. In the example first quoted it is recommended that h derived from f_1& f_2 is more reliable than estimates from either f_1 & f_4 or f_2 & f_4.

(b) <u>The Percentage of Quadrats with Only One Individual</u>

Graph 12 shows the relationship between "h", "f", and "p_1" (the percentage of quadrats with only one seedling), for all available data. The Poisson line is derived by calculation and the other points are from field observations by various authors. Only one point with a "h" value of 9 fails to fit into the general pattern. This point comes from data quoted by Thompson (1952) and is the only data showing two definite peaks at 0 & 2. Curves were drawn separating the various "h" values (ignoring this one point). These curves were extra-polated to 100% frequency.

This sort of graph may one day lead to the development of mathematical relationships giving p_1, p_2, p_3, ... etc.

for each "h". This has not been fully investigated, however the ratio p_1 (Poisson) over p_1 (h) for the same frequency f seems to increase steadily from f = 10 to f = 90%.

e.g. for h = 2 this ratio rises from about 1.1 at 10% to 1.3 at 90%, and for h = 5 this ratio rises from 1.3 at 10% to 2.0 at 90%.

The immediate value of the curves on Graph 12 is to short-cut the estimation of "d" and "h" from field observations of "f" and "p_1". Instead of a total count of all individuals on all quadrats, observations could be made of the following:-

(i) Quadrats with no individuals.

(ii) Quadrats with one individual.

(iii) Quadrats with more than one individual.

This method was tested against the same 8' radius data used previously:-

	8' radius	Quarter	Half
f	77.8	40.7	58.3
p_1	21.0	19.5	24.1
h	3.9	4.2	4.2
h from Graph	3.6	5.2	4.2

This method seems to give a reasonable estimate of heterogeneity from which can be obtained an estimate of the density. However, it should not be forgotten that p_1 is always less than f and is correspondingly less reliable, especially at the lower frequencies. A further trap is the possibility that the population may have more than one peak in which the relationships on Graph 12 no longer apply. Fortunately this seems to be a rare occurrance.

Both short-cut methods are weakest at low frequencies, however in this case a total count is nearly as easy as either short-cut method and gives much more reliable information.

Recommended Methods of Measuring Heterogeneity

$$h = \frac{do - dm}{dr - dm}$$

The best method of estimating "h" is to count all seedlings on about 200 quadrats. In the following example 155 quadrats were used:-

Count all individuals	107	(1)
Count all stocked quadrats..	84	(2)
Divide (1) by 155.. .. "do".	0.690	(3)
Divide (2) by 155.. .. "dm".	0.542	(4)
Subtract (4) from (3). "do-dm".	0.148	(5)
Read "dr-dm" from dm from Graph 5.	0.238	(6)
Divide (5) by (6).. .. "h"..	0.62	

The above data was obtained by marking oviposition holes of Sirex noctillio on transparent plastic wrapped around a tree. The subsequent plan was superimposed onto standard graph paper and the quadrat size designated as one square inch.

If an estimate of "h" is desired without having to count all individuals one or other of the "short-cut" methods can be used as long as their pitfalls are known and as long as 100 to 200 quadrats are used. The heterogeneity can be read directly from Graph 11 or Graph 12.

In any case if the frequency is about 10% or below a total count is advised as being more accurate but not much more trouble than the short-cut methods.

If "d" and "f" are known "h" can be estimated directly from Graph 4.

Summary of the Properties of "h"

This new factor of heterogeneity is derived from a combination of frequency and density. It is a measure of the aggregation or "clumpiness" of the distribution. It appears to be constant for a range of frequencies and for a range of quadrat sizes. This constancy suggests that it is a measure of the factors that produce the clumpiness of the distribution that may be independent of such variables as quadrat size and seed crop intensity. In this sense it is a better measure of the distribution than either density or frequency which are related to quadrat size.

"h" is a measure of departure from randomness of a distribution which does not involve the determination of variance and which may be largely independent of quadrat size. Moreover it is possible to assess the heterogeneity of data where only "f" and "d" are given without the full information on frequency of numbers of quadrats with 1, 2, 3, etc seedlings.

Through this factor it is possible to estimate frequencies for quadrat sizes other than that actually used and so derive stocking standards in a logical manner for any quadrat size.

When insect populations are studied it seems likely that changes in "h" in time may be indicators of changes in the environment that the fluctuations of both frequency and density only tend to obscure. Similarly, differences in "h" between different treatments in a sowing trial can measure real differences between treatments having identical densities.

The limitations of "h" are several. No factor can be calculated if the frequency is 100% or if the quadrat area is such that no quadrat has more than one seedling. These two limitations can generally be overcome by a change in quadrat size.

A further limitation is that the theory of constancy of "h" with quadrat size fails when suitable seedbed is patchily distributed. This can generally be overcome by mapping out patches of unsuitable seedbed.

It is suggested that, despite it's limitations, this new heterogeneity factor "h" increases the understanding of distribution patterns. It is recommended that all distributions to which it applies should be classified in terms of their <u>density</u> and their <u>heterogeneity</u>, and that the term <u>frequency</u> be avoided if possible.

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See also:

(i) List of references in APPITA paper in Appendix.

(ii) "The Interdependence of the Eucalypts and Forest Fire in Southern Australia" - Aust. Forestry 23. 3. - which summarises much of the ecological discussion in parts ID & IC.

APPENDIX 1.

REGENERATION SURVEYS FOR CUT-OVER AREAS OF ASH TYPE EUCALYPT FORESTS

A. B. MOUNT

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REGENERATION SURVEYS FOR CUT-OVER AREAS OF ASH TYPE EUCALYPT FORESTS[1]

A. B. MOUNT*

SUMMARY

This paper shows that regeneration arising after logging is not randomly distributed but clumped or aggregated. The effect of this aggregation on stocking is discussed for typical types of seed distribution. It shows how regeneration survey methods are used to discover the regeneration pattern, so enabling restocking measures to be most economically undertaken. Survey methods for two ages of regeneration are recommended.

This paper is based on experience gained while working for the Tasmanian Forestry Commission on the concession areas of Australian Newsprint Mills Ltd. Much of the information on forest growth and utilization methods relates only to this area, but all information concerning regeneration surveys should have general applications.

TERMS AND SYMBOLS USED IN THIS PAPER

Quadrat — Small portion of ground of known area

Milacre — Quadrat one-thousandth of an acre in area

Centracre — New term for one-hundredth acre quadrat

Sample — Set of observations made on several quadrats

Density — d — Average number of seedlings per quadrat per sample

Frequency — f — Percentage of quadrats stocked (having one or more seedlings)

Heterogeneity — h — New term defining the aggregation or clumpiness of a distribution

d_o — The observed density as obtained from a sample with frequency f.

d_m — The minimum density corresponding to a frequency f. (f/100)

d_r — The density corresponding to a random distribution whose frequency is also f.

THE PATTERN OF REGENERATION

This is the final product of the overlapping patterns of the four main factors, seed, seedbed, light, and protection of the seed and seedlings. Each factor is subject to certain modifications by logging, which produce different patterns of regeneration on cut-over areas from those found on un-logged areas.

Regeneration without logging — how nature does it

Dense regeneration of the ash type eucalypt forests closely follows a severe wild fire. Seed is shed fairly evenly on to the fire-cleaned seedbed. The understorey is destroyed and the light intensity on the forest floor is increased. The fire drives out or kills animals and insects and greatly reduces their effect over a wide area, giving the seed and seedlings protection until the new crop is established.

If all four factors are well distributed over the burnt area, ample well-distributed regeneration will occur. Where one or more of these factors are absent regeneration will fail. Such "failures" of a given species do occur in nature, and small patches of one forest type give way

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to another. Lack of seed at the time of the fire — due to insufficient trees with seed, or to a succession of poor flowering years — may result in a *Eucalyptus regnans* site being taken over by *Acacia, Olearia* or *Pomaderris* species. Lack of suitable seedbed and light — where wet gullies are only lightly burnt — may perpetuate rain-forest species. Lack of protection — from animal re-invasion at the edge of the burn, or from a later fire — may cause the site to become overrun with *Pteridium* or other ferns.

Regeneration following logging

Reduced seed: Perhaps the most important effect of logging is the reduction of seed available for regeneration. The percentage of the original seed left on standing trees after logging may range from less than 10 per cent (clear felling with only culls remaining), to perhaps 70 or 80 per cent (selected dominants left as seed trees), or possibly even more in certain selection systems. If regeneration treatments are carried out before logging 100 per cent of the original seed may be available for regeneration, but not all of this can be effective because of damage to the regeneration by subsequent logging.

Seed on felled heads seldom produces regeneration. If the coupe is burnt after logging this seed is destroyed by the fire; if it is not burnt there is generally no seedbed available and light is inadequate because of slash. This seed can be used only if the seedbed is prepared before felling.

Aggregation of seed supply: The distribution of seed shed from a standing tree is necessarily uneven, more being shed under the tree than at a distance from it. The size of the patch varies with the species: Douglas fir can disperse "adequate seed" up to 40 chains from a seed edge (1), *E. regnans* probably only 5 chains. Few *E. regnans* trees would carry enough seed to provide adequate regeneration more than 1½ to 2 chains from the seed trees, thus making the regeneration patches relatively small. The distribution of *E. regnans* seed is, therefore, likely to be more clumped, or aggregated, than that of Douglas fir. The actual distribution over an area is dependent on the number of trees-with-seed to the acre, the intensity of the individual seed crops, and the wind strength and direction at times of seed fall. The fewer the trees-with-seed, the more aggregated the seed distribution. If the trees are felled on to prepared seedbeds their seed crops are even less well distributed.

Aggregation of suitable seedbed: Soil burnt clean, or very lightly disturbed, is the best seedbed for the ash type eucalypts; unburnt vegetation, logs, stumps and heavily disturbed, compacted or puddled tracks, are the very worst.

With tractor logging followed by burning, the best seedbed is found at the far ends of the tracks (where the soil was run over only once and by an unloaded tractor), at the extreme edges of most tracks, and where the slash is well burnt.

After high-lead logging there is a relatively small area of heavily disturbed soil present and a slash burn usually produces ample seedbed where the slash is continuous. As with tractor logged coupes the fire will tend to go out before it reaches the edge of this area if no preparation is made before burning.

Where disturbed seedbeds are favoured because of the difficulty or danger of slash burning, logging without special treatment of the coupe edges and inter-track areas will produce a clumped distribution of seedbed.

Tracks tend to congregate towards the loading out points, fires tend to peter out before reaching the edge of the coupe. Unless the coupe is treated to obtain a better distribution of these seedbed forming factors, the best seedbeds will occur towards the centre of the coupe and along road and track edges.

Poor distribution of light: The light intensity and distribution on a coupe after logging varies with the logging method and stand density. Generally, high-lead operations let in more light than tractor logging but both methods leave the edges of the coupe in shade. Fire can destroy most of the shade in the middle of the coupe but it hardly affects the edges unless proper preparations are made.

Reduced protection: After logging and/or slash burning the animals quickly re-invade from the edges of the coupe, and the insect seed predators return. Some protection is offered to seedlings by logging debris, but large logs and the logging tracks become the main access routes for browzing animals. Destruction is probably greatest at the edges of the coupe. Seedlings in dense clumps survive due to weight of numbers, or are found in patches inaccessible to the browzing animals. Only protection from browzing will prevent this clumping tendency.

Subsequent fire, if it does not kill all the regeneration, will have a further clumping tendency. The dense clumps, because they are associated with either extensive areas of disturbance or with well burnt slash, are less likely to be re-burnt than the rest of the coupe.

The final pattern of regeneration

Without special treatment: Most logging operations cause all four factors to become aggregated. Regeneration occurs around trees-with-seed, in dense patches wherever suitable seedbed receives both light and protection, and near the centre and road edge of the coupe.

Following regeneration treatments: Where treatments such as those used by Australian Newsprint Mills Ltd. (2) are applied to extend the influence of these four factors evenly over the entire coupe good regeneration is assured. However the seedling distribution following logging will be rather more aggregated than after wild fire in the uncut stand. The effect of the varying degrees of aggregation is discussed in the next section.

In other forest types other factors may be more important than those described above but each type will have its own distribution which will contribute to the seedling distribution. However, it is almost certain that the distribution of the seed is the most important factor in seedling distribution.

THE EFFECT OF THE REGENERATION PATTERN

It was shown in the previous section that the regeneration following logging is not evenly distributed but tends to occur in clumps. What does "evenly distributed" mean, and how can this "clumpiness" be measured and described?

Results of various patterns of seed distribution

A random distribution: If the seed were randomly distributed and all developed into seedlings, the resultant regeneration would have no large gaps or dense patches. This, the poisson distribution, is the most "even" of all natural distributions: only in artificial distributions like plantations are the individuals more evenly spaced. This is the most "homogeneous" natural distribution and although it rarely occurs in tree seedling distributions it is a convenient yardstick with which to measure them. In this paper it is assigned a "heterogeneity factor" (or "clumpiness") of unity.

Broadcast sowings: Broadcast seed is generally spread fairly evenly over the area by hand or aerially. However the seedlings are generally not quite as evenly spread as for a random distribution, but have factors between 2 and 3.

Selected seed trees: Where, say, five seed trees have been reserved per acre there must be five or less clumps of regeneration. This makes the distribution worse than for broadcast sowings. Factors of from 3 to 5 are the most likely with the factor high when only a few of the selected trees actually carry seed.

Cull seed trees: Where cull seed trees are the only seed source the distribution tends to be very heterogeneous with factors from 5 to 10 or higher.

Spot sowings and plantings: In these distributions the spacing of individual or groups of seedlings is controlled and heterogeneity is not important. The assessment of this type of artificial regeneration is discussed later.

The effects of the distributions of other regeneration factors

In discussing the effect of the seed distribution it was assumed that the other factors were "about average," but seedbed, light, protection and seedling age can also affect the heterogeneity of the regeneration distribution through the heterogeneity of their own individual distributions. An example of this will be given after the next section.

Measures of stocking

Density: The oldest and most common measure of stocking is the number of trees per acre. A similiar measure is "density" which in this paper is defined as the mean number of seedlings per sample plot or quadrat. If regeneration is being assessed on one-thousandth-acre ("milacre") quadrats then a total of 60 seedlings found on 100 milacres gives a density (d) of 0.6 equivalent to about 600 seedlings per acre.

The disadvantage of this measure is that it gives no indication of the distribution of these 600 seedlings, they could be all in one small patch and the remainder of the acre bare.

Frequency: If instead of counting the seedlings on each quadrat only their presence or absence is recorded, the percentage of quadrats with seedlings present, or "frequency" gives a different measure of stocking. *e.g.* 100 milacres inspected, 30 have seedlings present, frequency (f) equals 30 per cent.

Although a better measure than density, frequency also has failings. It was found that there was no fixed relationship between the two measures; 30 per cent in one area might mean that there were 500 trees per acre, in another, 1,000. It was found that 30 per cent was an acceptable stocking in one area (from other observations) but in another it was too low. Also, in the extreme case 30 per cent stocking could mean that 70 per cent of the area, in a contiguous patch, was devoid of regeneration.

Heterogeneity: It now appears that frequency and density can be correlated through another factor — heterogeneity. This factor is derived as follows:

$$\text{heterogeneity (h)} = \frac{d_o - d_m}{d_r - d_m}$$

where (d_o) is the observed density of a distribution of frequency (f).

and (d_m) is the minimum density possible with a frequency (f).

and (d_r) is the density corresponding to a random distribution whose frequency is also (f).

Example: Suppose 100 milacres are examined and 30 of them contain seedlings. Suppose all seedlings are counted and that on the 100 milacres there is a total of 60 seedlings. What is the heterogeneity factor for the distribution so sampled?

Frequency (f) is 30 per cent, density (d_o) is 0.6

Minimum density (d_m) is 0.3 and the equivalent random density (d_r) is 0.357 (This figure is derived from the relationship d_r equals $\log_e \left(\frac{100}{100-f}\right)$. It can be more easily obtained from tables such as provided by Grieg-Smith (3).

$$\text{hence (h)} = \frac{0.6 - 0.3}{0.357 - 0.3} \text{ or } 5.3.$$

The derivation of this relationship will be discussed more fully in another paper. The two main properties of this new measure are these:

(h) is constant for various frequencies for the same type of distribution. *e.g.* in one area a given system of management is likely to produce the same heterogeneity factor while measures such as density and frequency will depend on other factors such as seed crops intensity *etc.*

(h) is constant for various quadrat sizes providing that factors other than seed are reasonably homogeneous. *e.g.* all burnt seedbed *etc.*

Absence: This measure of stocking, or rather, lack of stocking is perhaps the most important silviculturally. If the most important silvicultural task is to obtain full stocking, it is far more important to know *how many gaps* there are than to know either the number of trees per acre or the stocking in terms of milacre frequency.

Suppose the very lowest stocking that would be tolerated on an acre is 100 perfectly spaced trees, then any patch of ground in a stand over one-hundredth of an acre in size and bare of seedlings is a "gap."

If these one-hundredth acre patches are called "centacres," how many empty centacres should be tolerated before undertaking restocking measures?

The answer to this question may lie in a consideration of fully stocked natural stands of regrowth. Hall (4) showed that for *E. obliqua* in Victoria it is unlikely that more than 230 trees per acre will attain a nominal minimum merchantable breast height diameter of 10 in. It can be assumed that these 230 trees approximate to a random distribution over the acre, due to competition in the fully stocked stand. If this is true the centacre gaps between these stems would average 10 per acre. That is, the percentage of centacres not carrying one of these 230 trees would be 10 per cent (absence is 10 centacres). SEE FIG. 6

Bowling (5) has shown that for *E. regnans* in Southern Tasmania it is likely that only 150 trees per acre attain 10 in. diam. breast height (absence of 22 per cent centacres). As minimum merchantable sizes tend to fluctuate with time some allowance should be made for possibly smaller sizes in future by using a low absence figure to obtain suitable minimum stocking standards. It is important to note that this is still a minimum standard for seedlings even though an optimum for merchantable stems: these fully stocked regrowth stands almost certainly started with 0 per cent centacre absence, therefore allowing 10 per cent centacre absence in young seedlings it is almost certain that this figure will increase due to early deaths.

Measuring the distribution

Before discussing stocking standards a few explanations should be provided for the heterogeneities given by the various forms of seed distribution and how they were derived.

These factors are based on the interrelationship of density and frequency in the one sample as has been shown. Several authors have published data on their local frequency/density relationship. Both extensives and intensive surveys measuring frequency and density have been carried out near Maydena Station, even

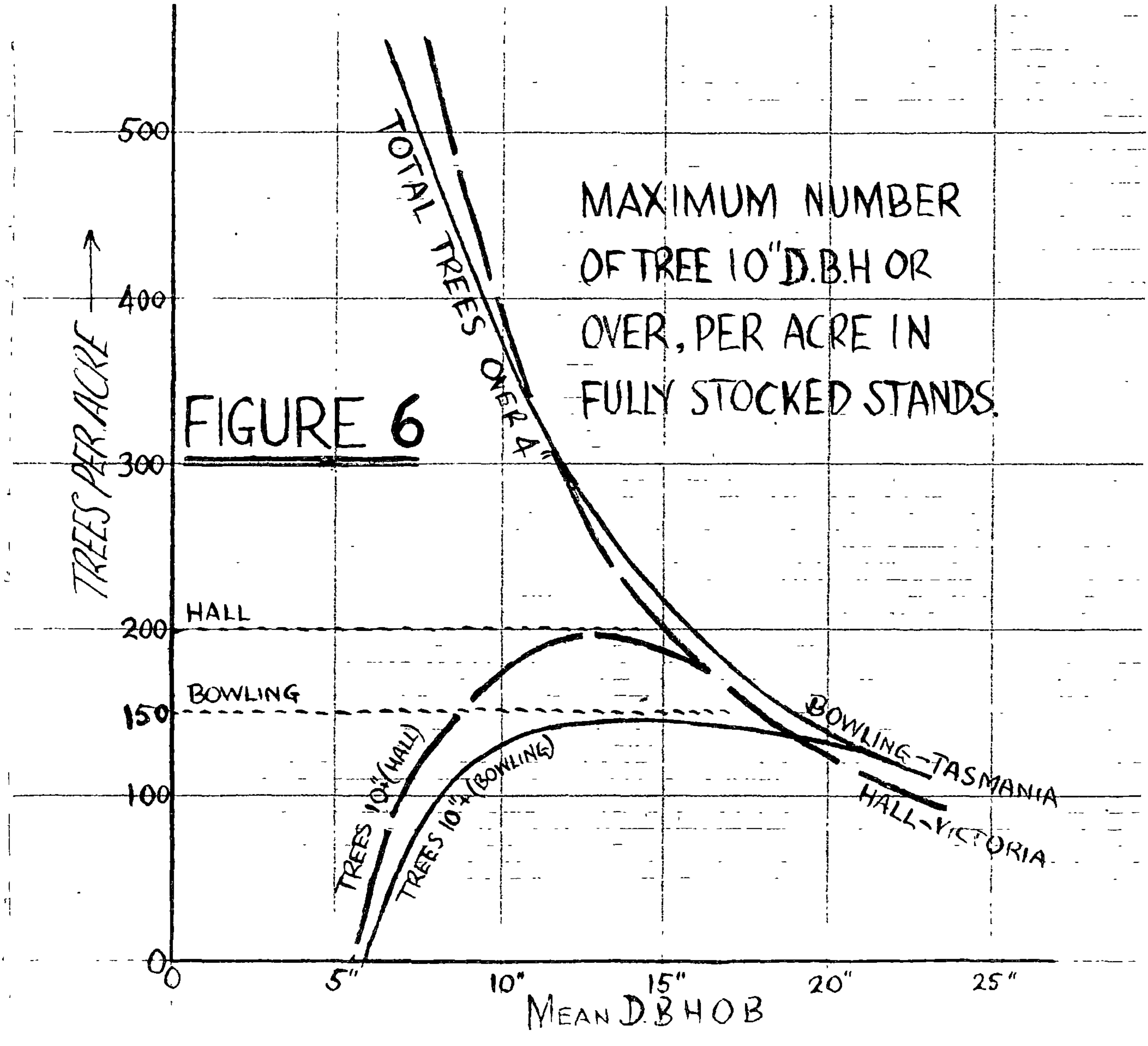

FIGURE 6
MAXIMUM NUMBER OF TREE 10" D.B.H OR OVER, PER ACRE IN FULLY STOCKED STANDS.
TREES PER ACRE
MEAN D.B H O B
0
100
150
200
300
400
500
0
5"
10"
15"
20"
25"
HALL
BOWLING
TOTAL TREES OVER 4"
TREES 10"+ (HALL)
TREES 10"+ (BOWLING)
BOWLING-TASMANIA
HALL-VICTORIA

though density is not now measured. Comparing all available data it appeared that the average heterogeneity factor was about five. Artificial sowings about two to three and distributions with obvious clumpiness from 10 upwards.

It is likely that these clumpy distributions in tall trees like *E. regnans* are due mostly to very heterogeneous seedbed conditions, while in short plants with large heavy seeds the physical inability to spread their seed any distance is more likely responsible.

Example: Suppose an area has only half its seed bed receptive to seed germination (*e.g.* half burnt, half unburnt *E. regnans*), and suppose the stocking on the two halves to be:

Good seedbed (f) 60% (d) 1.86 (h) 4.0
Bad seedbed (f) 4% (d) 0.0436 (h) 4.0

If the area had been surveyed the stocking disregarding the seedbed would have been:

Both seedbeds (f) 32% (d) 0.952
giving a factor (h) of 17.6!

This sort of heterogeneity does not remain constant for all quadrat sizes and frequencies, but tends to rise and fall with both. However, mapping out of such unreceptive seedbed can usually reduce this effect to a minimum.

STOCKING STANDARDS

Existing standards

Several authors have suggested minimum stocking standards in terms of the frequency of milacres stocked (6) (7) (8) (9) (10) (11) (12) (13).

It is apparent from all these sources that below 30 per cent is considered understocked and above 40 per cent, sufficiently stocked. It is likely from this evidence alone that the minimum stocking standard should be set between 30 and 40 per cent for most species.

"Centacre" stocking as a standard

It is proposed that the minimum stocking standards be defined in terms of the frequency of "centacres" stocked: 90 per cent for unestablished regeneration and 85 per cent for established regeneration. This is based on the previously mentioned assumptions and a consideration of likely seedling mortality. Working from this new standard it is possible to derive the minimum standards appropriate to distributions of different heterogeneities in terms of milacre frequencies and densities.

Derived stocking standards

Below are given the equivalent milacre standards corresponding to centacre frequencies of 90 and 85 per cent are given in Table 1.

Seedling mortality

Most value will be obtained from a regeneration survey if it is made at an early age when any "filling" measures required are both easy and economical. But how many seedlings are going to become established? If the survey is made at the latest possible date before filling operations would normally start, and if only tall healthy seedlings are tallied, or if a minimum of small seedlings be counted as equivalent to one tall seedling, this effect of seedling

TABLE 1.

MILACRE FREQUENCIES AND DENSITIES CORRESPONDING TO CENTACRE FREQUENCIES OF 85 AND 90 PER CENT

Heterogeity factor — h	Centacre frequency				Remarks
	90%		85%		
	f	d (per acre)	f	d (per acre)	
1	21	.230 (230)	17	.186 (186)	Random distribution.
2.5	30	.442 (442)	25	.344 (344)	Broadcast sowings.
5	36	.791 (791)	31	.609 (609)	Average seed trees.
10	39	1.493 (1493)	35	1.132 (1132)	Very clumped distribution.

where f is the milacre frequency and d the milacre density.

TABLE 2.

A COMPARISON OF "STOCK MAPPING" AND MILACRE SCORES FOR TIM SHEA LOGGINGS

Area (acres)	Stock mapping Type	Trees per acre	Milacre scores for the same area
9	Very dense	2600	f = 100% : d = 1.50 (only 2 mils.)
16	Dense	530	f = 75% : d = 2.00 (only 4 mils.)
101	Enough	210	f = 37% : d = 0.95 (19 mils.)
90	Scattered	97	f = 35% : d = 0.53 (17 mils.)
216	All stocked	348	f = 42.9% : d = 0.905 (42 mils.) (h = 7.8 (905 trees per acre)
356	Understocked	21	f = 3.3% d = 0.033 (60 mils.) (h not measurable) (33 trees per acre)

death will be minimized. However to allow for the deaths that will almost certainly occur the minimum standard should be derived from a 90 per cent centacre stocking.

Comparative methods

In the past most minimum standards have been derived by assessing stands deemed by observation to be just satisfactory (6). If instead several stands are milacre surveyed and later assessed by a different form of survey (see "Stock mapping" later), the minimum standards can be derived quantitatively and seedling mortality taken into account.

REGENERATION SURVEY METHODS

What will a regeneration survey do?

To be of greatest value, a regeneration survey should give reasonably accurate estimates of

- the overall regeneration position,
- the proportion of the area understocked,
- the approximate location of the understocked patches, and
- the problems to be overcome before full stocking can be achieved.

Two types of survey have been developed in the Florentine Valley, a type of "stock mapping" to produce a map of older regeneration on which to base future management, and the more common type of survey used to discover what regeneration is present at an early age when economic restocking of the gaps is possible.

Stock mapping older regeneration

This system applies only to those species which have a fast initial height growth compared to the competing vegetation. It is used in the Florentine Valley area with eucalypts growing in competition with ferns and fireweeds. Similar surveys are made in Malaya for inventory purposes (15) (16).

Timing the survey: Enough time must have elapsed since the regeneration was initiated, for the greater height growth of the seedlings to make them obvious from at least one chain away. In the Florentine Valley this is from about age four years onwards. At this age the eucalypts are from 6 ft. to 20 ft. high, above a fairly uniform layer of vegetation 2 ft. to 4 ft. high. A small percentage of eucalypts are generally still alive below this competing vegetation, but even if they do eventually emerge they will not alter the final stocking very much. (In the Florentine Valley area the ferns *Hypolepis rugosula, Histiopteris incisa* or *Pteridium esculentum* develop dense mats of dead fronds which tend to bury tardy seedlings, especially after snow).

Method: The procedure to be followed is set out in Fig. 1. Parallel strips are run at 5 chain intervals and all trees counted within one chain either side of the line. Booking is broken at one chain intervals to produce pairs of 1/10th acre.

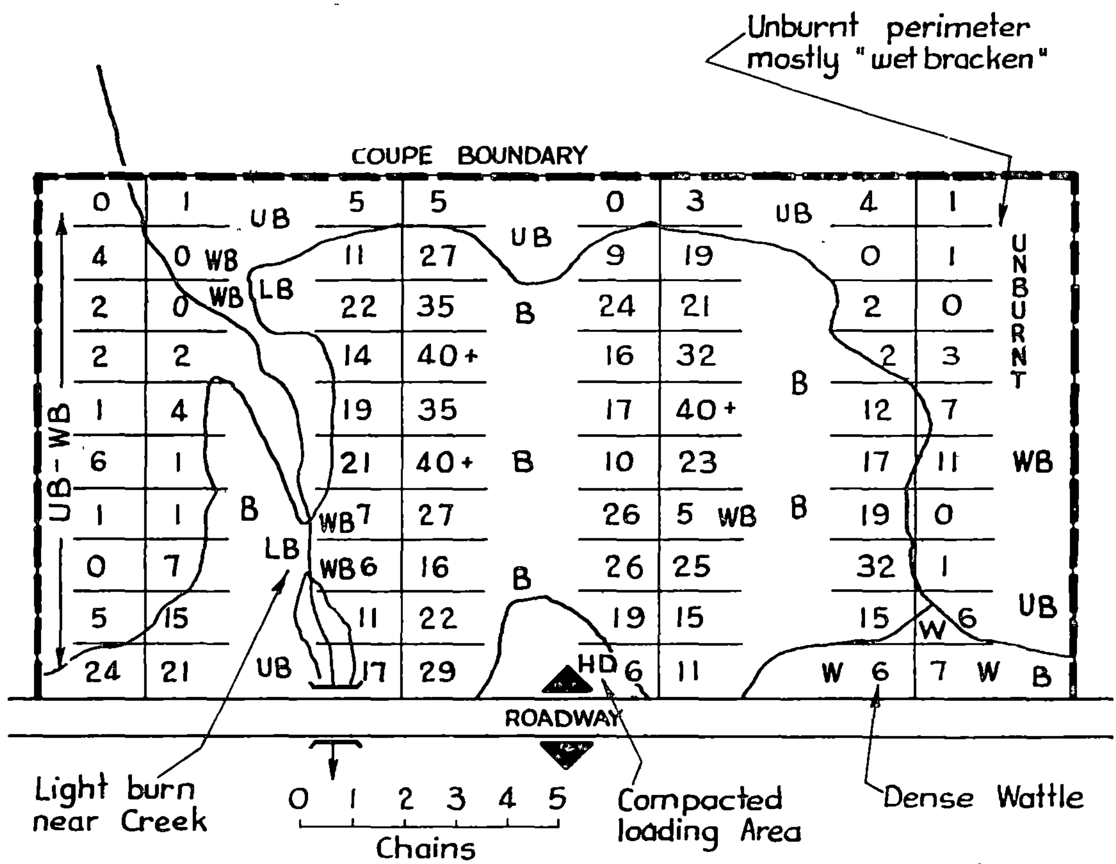

Fig. 1. **STOCK MAP OF OLDER REGENERATION**

UB—unburnt: LB—light burn: B—burnt: WF—wet ferns (*Histiopteris* **and** *Hypolepis* **spp.): W—wattle: HD—heavily disturbed.**

Numbers given are total seedlings in 1 chain x 1 chain area.

Counts are made from the centreline with only occasional checks of the 1 ch. distance to the edge of the plot. Counts are necessarily an underestimate as shown in Table 2. Although biased, they are a quantitative method of stocking, especially of the trees most likely to become crop trees. Booking is best done on to prepared map sections taken into the field. (see Fig. 1).

Recommended survey practice for young regeneration

Regeneration surveys of 1 to 2 year old regeneration, where very small seedlings are searched for, necessitate small quadrats. The milacre quadrat is the one most commonly used, either as a 6.6 ft. square or as a circle 3.72 ft. radius. In this paper all surveys using milacre quadrats are called "milacre surveys."

Timing the survey: The survey should be made after the maximum number of seedlings have appeared but as late as possible before restocking measures would be started if required. If sowings are normally made in March or September, surveys should be made in February or August.

Layout: Parallel strips are run at 4 chain intervals to cover the whole area to be assessed. Circular milacre quadrats are inspected at one chain intervals along each strip. If the stocking is marginal (of between 20 and 40 per cent) it may be necessary to run further strips between the existing ones to improve the accuracy of the final regeneration map. With practice very accurate maps can be produced using only a compass and pacing the chainage.

Number of quadrats: Where the stocking is very low (0-10 per cent) or very high (70-100 per cent) as few as 20 quadrats may suffice but only if they are evenly spread over the coupe; 100 milacres should give a fairly accurate overall stocking figure if this is required.* If a map of the regeneration is the prime concern the 4 x 1 chain layout and the size of the area should determine the number used.

Tally for Quadrat: (See Fig. 2). (i) Record the presence of the first seedling seen on the quadrat either as a tick, or better in terms of it's approximate height in inches. Do not count seedlings that are obviously not going to survive. If the only seedling on the milacre is exceptionally small or unhealthy it is perhaps worthwhile giving the milacre "half-stocking" and not counting this milacre as contributing to the overall frequency but counting it as stocked for mapping purposes. Two or more seedlings on the milacre make it "stocked" for both purposes.

(ii) If the milacre is unstocked but an inspection of surround shows that there is a seedling nearby, the "surround" column is ticked. (If desired it is possible to make this surround into a four-milacre quadrat by counting only seedlings within 7.44 ft. of the peg).

(iii) Note the nature of the seedbed (burnt, disturbed, *etc.*), the secondary vegetation, browzing damage or any other information peculiar to the milacre which is likely to affect the regeneration or the accuracy of the final map.

Tally for coupe: All general information pertinent to the likely success or failure of regeneration should be noted. Creeks, change of aspect, rock outcrops or other information likely to help mapping or future location of understocked areas for sowing, should also be noted.

Regeneration map: If the area is not obviously empty or fully stocked a map should be prepared. A plan is prepared showing strips and stocked, surround-stocked and unstocked milacres. The boundary between stocked and understocked areas is then drawn using the following rules:

(i) if the milacre is unstocked it can only be in the stocked area if it is surround-stocked or if both its neighbours on the strip are stocked or surround-stocked.

(ii) if the milacre is stocked it can be in the understocked area if its neighbours are neither stocked nor surround-stocked.

(iii) it is generally inadvisable to pull out stocked or understocked sections of strip under three milacres in size unless other survey information shows that they are representative of the area (*e.g.* small patch of unburnt seedbed).

(iv) if a stocked section falls below 30 per cent frequency, because of an unusually high ratio of surround-stocked to stocked milacres, it is likely that the seedling distribution is unusually homogeneous and it should be accepted as stocked. This case will, however, be extremely rare. If the stocking falls below 30 per cent for any other reason the strip should be rechecked to remove understocked sections.

Once the boundaries of stocked and understocked have been established on the strips they should be extended across the 4 chain gap between the strips taking into account any features that might account for the change in stocking. The stocked boundary should not be drawn from a stocked strip to less than two stocked milacres in an understocked one, unless field observations show that this is justified.

It will be noted that the question of stocking standards is practically avoided. This method of mapping will produce understocked areas of 0-10 per cent and stocked areas of 40 per cent plus frequency which will satisfy all minimum stocking standards.

Results: From the map stocking figures are now calculable; for the whole, for the stocked and for the understocked portions. These figures, although of value for legal or comparative purposes, are not of great value in planning restocking measures.

The map shows the location of the understocked areas and the total milacres in this type will give an estimate of the area understocked (4 x 1 chain layout equals 2.5 milacres per acre). This suggests that there is a much better way of determining legal minimum stocking than by frequency of milacres. If the law requires a regeneration survey anyway it should state its minimum standard as a maxium permissable proportion of the area

*Twenty subsamples of 100 to 107 milacres were taken from a very intensive experimental milacre survey in the Styx Valley, Tasmania. These subsamples had frequencies ranging from 21.7 to 31.7 per cent with a mean of 27.0 per cent (2 x 1 chain layout). Doubling the sample information reduced the range to 24.6-30.7 per cent for a 2 x ½ chain layout, and to 26.2-28.7 per cent for a 1 x 1 chain layout.

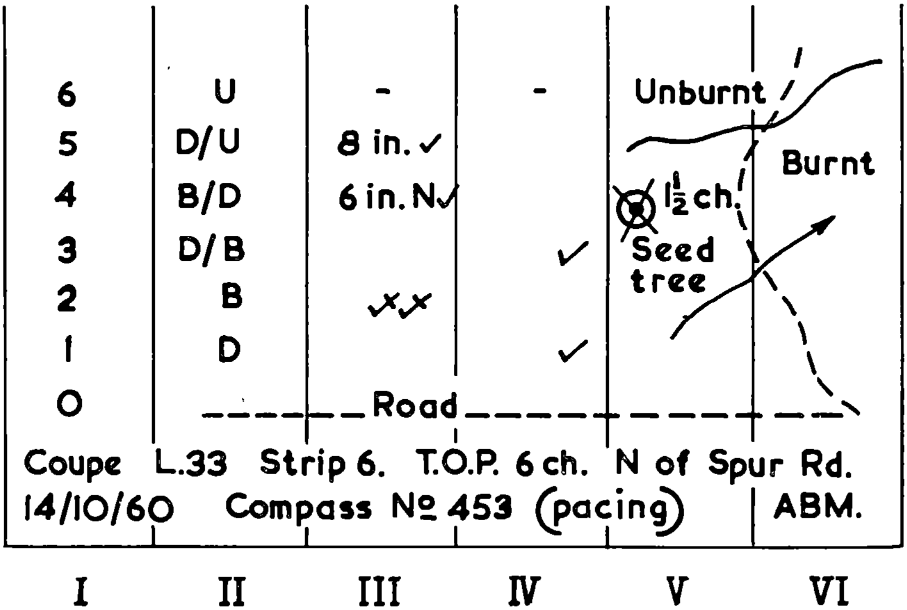

Fig. 2.

SURVEY BOOK FOR MILACRE SURVEYS

I. Distance in chains from start of strip. It is generally convenient to start from the road as this simplifies the mapping; however, this practice means that a chain-wide strip by the road is undersampled. If this bias is considered important (*e.g.* if area is small) it is better to put the first quadrat at some randomly selected portion of one chain from the start of the strip.

II. Seedbed on milacre. B—burnt: D—disturbed: U—unburnt.

III. Stocking on the milacre. The presence of a tick followed by "8 in." indicates at least one established seedling present, height about 8 in. N—some browzing damage observed. A crossed tick indicates one unestablished seedling. Two crossed ticks show that at least two unestablished seedlings were seen.

IV. Stocking on the surround.

V. and VI. Survey information.

understocked after a regeneration map has been prepared.

Understocked areas located in the first survey should be re-surveyed after treatment to assess success or failure.

Assessing artificially sown areas

Spot Sowings: Theoretically the method of assessing a systematic spot sowing by a systematic grid of milacres is a very doubtful procedure. However, in the Florentine Valley, where spot sowings are not strictly systematic because of logs, unsuitable seedbed and human factors, the method of regeneration mapping works very well. This is due to at least three factors: the diameter of the milacre is over 7 ft., the nominal spacing of spots is usually 7 ft. x 7 ft. and the method of inspecting the surround if the milacre is unstocked.

Another system tried successfully is the marking of all spots on a proportion of the rows with red painted wire pegs at the time of sowing. The success of the treatment can then be assessed by following the lines of red pegs. If the spots are not so marked a high proportion of the unsuccessful spots are missed. This is similar to "survival counting" in plantations but with the bias that the sower knows that the pegged rows will be the only ones counted. This bias can be minimized by changing the pegger in the sowing team several times each day. This may even tend to raise the overall standard of the sowing operations.

Where spots are sown at spacings greater than 7 ft. x 7 ft. the mapping should be modified to allow for a lower minimum standard, if a milacre survey is used. However with spacing greater than 7 ft. x 7 ft. pegging is an even more favourable method.

Broadcast sowings

This form of artificial sowing is assessed in the same way as natural regeneration with the possible modification of rule (iv) to 25 per cent when producing the map of regeneration.

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DISCUSSION

W. E. Cohen: Is there any significance in the dispersal of loading points?

A. B. Mount: The diagram shows the effect of loading with a mobile machine instead of a fixed loading point.

M. J. Hall: What man-power would be required to do an adequate regeneration survey on a 1,000 acre per year cut?

A. B. Mount: If the average coupe size is twenty-five acres, about forty will be cut per year. It would be necessary to put in 100 milacres in each coupe. This could be done by a two-man party in half a day per coupe. Analyzing the result might make the one day per coupe, or two by forty man days per 1,000 acres.

M. J. Hall: Is there any attempt made to find a new dozer track for each trip?

A. B. Mount: In very heavy understorey it takes quite a lot of time to break in tracks. It is uneconomic to do this for every log. More emphasis is placed on the use of fire to produce a suitable seedbed.

D. T. Kitchener: Could you give a brief description of your method of carrying out a regeneration survey?

A. B. Mount: This is covered in detail in the written paper, but it basically consists of looking very carefully at a large number of very small plots making up a very small sample. These plots are generally milacres systematically spaced over the coupe.

T. M. Cunningham: Could you say something about the size of the unstocked areas and the location of these?

A. B. Mount: The size of the understocked area can be estimated by graphical means and the location of the area approximated by drawing a line around the stocked milacres.

A. H. Crane: If the stocking level is much below thirty per cent on milacre plots, would you suggest treatment, and would you do a further more intensive survey of the area to locate the empty spaces?

A. B. Mount: The survey will show the heterogeneity of the seedling pattern. If it is close to random then even twenty per cent would be acceptable. If it is clumped it should be possible to locate the clump and treat the areas between them.

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APPENDIX 2.

STANDING INSTRUCTIONS FOR REGENERATION SURVEYS.

PART I. MILACRE SURVEYS FOR YOUNG REGENERATION. ($\frac{1}{2}$ to 4 yrs.)

A. INTRODUCTION. - The need for small plots, the circular milacre and its establishment, the percentage of milacres stocked, and the best time to survey.

B. FIELD WORK. - Strip and Plot layouts and booking procedure.

C. OFFICE WORK. - Mapping rules, results, design of treatments and re-locating the area requiring treatment.

D. ASSESSING THE EFFECTIVENESS OF THE TREATMENTS.

A. INTRODUCTION.

Where very small seedlings are to be assessed only small plots can be efficiently inspected. The standard plot is the circular milacre (one thousanth of an acre in area). In practice the "milacre stick" should be used. This consists of a steel peg which is jabbed vertically into the plot point, to which is attached a 3' 8-2/3" long radius wire. The wire is free to move around the peg or up and down it.

In assessing regeneration the wire is pulled taut and moved round in a circle about the central peg. The process is continued only until one seedling is found within the milacre. When several milacres have been assessed, it is possible to work out the percentage of milacres which are "stocked" (that carry one or more seedlings). This percentage of milacre stocked is the most commonly used measure of regeneration.

To provide the most reliable information, milacre surveys should be made AFTER the maximum number of seedlings have germinated but as late as possible BEFORE restocking treatments would be undertaken if required. When three or more years have elapsed since the burn a milacre survey is less efficient than other types of regeneration Survey.

B. FIELD WORK.

1. STRIPS. Parallel strips should be located at 4 ch. intervals to cover the whole area to be assessed. It is often convenient to use the road as a baseline and to run the strips at right angles to it. The first strip should start at a randomly chosen point between 0 and 4 chains from the edge of the area.

   If the results obtained from this 4 ch. grid are insufficient, intermediate strips may later be run to form a 2 ch. grid. Intensification of the survey in this way may be required where the area is less than 30 to 40 acres and the stocking is marginal, or in patches of larger areas where stocking is marginal. Stocking for this purpose is deemed marginal where the mapping rules tend to map out understocked areas above 10% milacre stocking.

   Strip direction should be maintained by compass. Plot spacing can in most cases be measured by pacing. Pacing greatly simplifies the field work but the assessor should check his pacing from time to time. The best test is to compare the length of a strip between two points obtained by pacing with that given by an existing survey. Tests of pacing against a tape over short distancesor on the even surface of a road are not comparable to that obtained on the whole strip. In very rough or steep country paces can be estimated over short distances but the final pace to the plot point should always be controlled by the legs and not the eyes.

2. PLOTS. Plots should be spaced at 1 ch. intervals along the strips. It is convenient, for mapping purposes, to put the first plot in at one chain from the road. This means that, although the area within one chain of the road is sometimes undersampled, the plot number and its distance from the start of the strip correspond.

   The plot point must be selected with the minimum bias. The assessor must therefore try to avoid looking where his last pace will fall. He should then implant his milacre stick either immediately in front of his toe or at some fixed distance in front of it.

At the end of the strip the assessor proceeds for 4 ch. at right angles to the strip direction to plot zero on the next strip. If this plot happens to be well inside the boundary of the area he should establish plots numbered -1, -2, -3 etc. until that boundary is reached. Then starting again at plot zero he should proceed back towards the road with plots numbered 1, 2, 3 etc. Should plot zero fall outside the area he should still proceed back to the road with plots 1, 2, 3 etc. but he need not assess them until the boundary is passed. Some note should be made to explain why such plots were not assessed.

3. BOOKING. The standard green survey book should be used with one horizontal line being taken up with all the observations made at one plot point.

(a) At the start of each new area notes should be made covering the following:-

Location, Date, Compass Number, Pacing or chain, Name(s) of Assessor(s).

(b) At the start of each strip:- Take off point, Bearing.

(c) At Each Plot Point:-

Column 1 - Plot number (equals the distance in chains from the strip T.O.P.)

Column 2 - Nature of Seedbed, B.(burnt), D.(disturbed), U.(Unburnt and Undisturbed) etc.

e.g. (B. means that the last major occurrence on this site was fire, even if it used to be a track; similarly for D.)

If regeneration occurs on only one of the two or three seedbeds found on the plot the successful seedbed should be marked with a tick. It is often of value to know this when restocking an area.

e.g. D/B✓ = plot has disturbed and burnt seedbeds present, but seedlings only occur on the burnt seedbed.

Column 3 - Presence of one or more seedlings on the milacre is here shown by a tick. In addition seedling heights should be estimated and recorded here at regular intervals. If seedlings have been browsed a capital N. (nibbled) should be written next to the tick in this column.

Column 4 - This column is one of the most important for mapping purposes especially where the stocking is marginal. It should be used only when the milacre is NOT stocked. It should show the stocking within twice the (milacre) radius of the peg (7'5-1/3"). The presence of one or more seedlings in this area is indicated by a tick in Column 4. The area within 7'5-1/3" of the peg is four milacres. When the milacre is stocked the four milacre must also be stocked so no search of the larger plot is required. Where several milacres in succession are unstocked little time should be spent inspecting the 4 milacres.

However, as soon as some field observations (such as seeing a seedling between plots) suggest that the "stocked-understocked" boundary is being approached, greater care must be taken over the 4 milacre inspections. Similarly, the first few empty milacres after a series of stocked should have their corresponding 4 milacre plots thoroughly searched.

Columns 5 & 6 - These columns should show all survey information and field observations that may help to improve the accuracy of the "stocked-understocked" boundary, e.g.

Approx, location of:- seed trees; boundaries between good and poor burns, between burnt, unburnt, unlogged sites; wet gullies, change of aspect; rock outcrops etc.

(d) At the End of the Survey.

Notes should be made at the end of the survey, whilst still in the field, of all general information likely to be of value in determining the treatment required to fully stock the area. Some attempt should be made to discover any possible correlation between the understocked patches and such natural features as aspect, rock outcrops, etc. Sketch maps of these features are likely to be of great value to those who have to re-stock the area.

Notes should also be made of the most common seedling heights and the tallest and shortest seedlings. The effect of browsing should be estimated with a view to the need or otherwise for poisoning, e.g. "Severe browsing near uncut edge, light elsewhere etc."

C. OFFICE WORK.

If the area is not obviously entirely empty or fully stocked, a map should be prepared. A plan should be made showing strips and all plot points. At each plot point a sign is made to indicate whether the milacre is stocked, or the four milacre only is stocked, or neither are stocked (e.g. solid circle, hollow circle, and a cross, respectively.)

1. RULES FOR MAPPING NATURAL REGENERATION. The boundary between the "stocked" and the "understocked" area is drawn using the following rules:-

(a) if the milacre is unstocked it can only be in the stocked area if its 4-milacre is stocked or if both its neighbours on the same strip are either milacre or 4-milacre stocked.

(b) if the milacre is stocked it may be in the understocked area if its neighbours on the same strip are neither milacre nor 4-milacre stocked.

(c) Where a stocked milacre occurs after two unstocked plots following the end of a stocked portion of the strip, and where field notes suggest no obvious change in stocking all three plots may be added to the stocked portion of the strip.

e.g. if 1 = milacre stocked.
4 = 4-milacre stocked.
0 = neither stocked.

1,1.4.0.0.1 ; 1,1,1.0.0.1 : are stocked
but 1,1.4.0.0.4 ; 1,1,1,0.0.4 ; 1,1,1,0,0,0,1 are only stocked for the first three plots.

(d) It is generally inadvisable to pull out stocked or understocked sections of a strip of two plots or less in size unless other survey information shows that they are representative of the area (e.g. Under the only tree with seed, small patch of unburnt seedbed etc.) Where one or two unstocked plots are adjacent to a type known to produce NO regeneration (e.g. unburnt or uncut forest) they can be mapped out as understocked. Similarly one or two stocked plots near a roadside often indicate a real stocking near the road edge even though the rest of the area may have little or no regeneration.

(e) If a stocked section of strip falls below say 30% stocking by milacres but there is an unusually high ratio of 4 milacre to milacre stocking, it is likely that the seedlings are distributed in an unusually even way and the strip should be accepted as stocked. If the stocking falls below 30% for any other reason the strip should be re-examined to remove further understocked sections.

(f) Once the boundaries of the stocked and understocked areas have been established on the strip they should be interpolated between adjacent strips taking into account any features that might be responsible for the change in stocking. The boundary enclosing a stocked section of one strip should not be extended across to a single stocked milacre or 4-milacre on an otherwise unstocked strip, unless field observations show that this is justifiable. Even crossing four chains to two stocked plots (1 or 4 milacres) should only be done with caution.

This method of mapping tends to produce understocked areas with less than 10% milacre stocking, usually much less. If in a marginal area the stocking for the understocked portion exceeds 10% despite all mapping care, further strips should be put in to increase the sample. With twice the information now available and the strip interval row only two chains the boundary between strips can be more confidently drawn.

2. RULES FOR MAPPING BROADCAST SOWINGS. With broadcast sowings the seed is distributed much more evenly than from seed trees. This means that a lower percentage milacre stocking can be accepted for the marginal areas. Rule (e) should be modified to 25% when mapping broadcast sowings, otherwise all other rules apply.

3. RULE FOR MAPPING SPOT SOWINGS. Where spot sowings are not strictly systematic because of logs, unsuitable seedbed, human factors etc. and where the spacing of the spots is nominally 7' x 7' or less, mapping by milacres is very good. Again rule (d) should be modified to 25%.

For spots spaced at much greater than 7' x 7' the system is not adequate. For wide spacings a much better method is to peg all spots on a proportion of the sowing lines at the time of sowing. If the spots are not pegged a high proportion of the unsuccessful spots will be missed. Pegging has been successfully tried in the Florentine where the additional cost is more than offset by the reliability of the survey results. Pegs are usually 1' long pieces of fencing wire dipped in red paint. When pegging there is a chance that the spot sower may take special care and so introduce a bias. This bias can be minimised by changing the pegger in the sowing team several times each day. This may even tend to improve the overall standard of the operation.

4. RESULTS. From the map three stocking figures can be obtained, - the percentage milacre stocking for the whole, for the "stocked", and for the "understocked" areas.

Of even more value the area of each section is proportional to the number of plots in it e.g. number of plots multiplied by 0.4 (4 ch. x 1 ch.) or 0.2 (2 ch. x 1 ch.) gives the approximate area in acres of the type.

The map shows therefore how much area requires treatment and where it is.

5. DESIGN OF TREATMENTS. Other field nates combined with the map should also indicate the nature of the unstocked area and so help in the planning of restocking treatments, e.g. if understocked area due to poor burn on which the vegetation is now faily tall and well established - planting may be required, if vegetation is still low spot sowings may succeed, if due only to lack of seed trees in the area broadcast sowings would probably succeed, etc.

Restocking treatments should be recommended at the time of the survey because the assessor has the most complete knowledge of the area.

6. RE-LOCATING THE AREA REQUIRING TREATMENT. If several small understocked patches are mapped out without being obviously related to some natural feature there will be difficulty in finding these areas again when restocking. This can only be overcome by sowing rather more than the minimum area and by "wasting" a little seed.

The understocked areas should be either easily re-identifiable by some obvious natural feature (e.g. aspect, very poor burn etc.) or should be surrounded by a regular figure on the map including as much of the understocked area and as little of the stocked area as possible. It is better to re-sow a regenerated patch than to fail to sow an unregenerated one. This surround line should be clearly shown on the map along with all information required to find its take-off-point.

D. ASSESSING THE EFFECTIVENESS OF THE TREATMENTS.

The treated areas should be assessed later as previously described, to gauge their success and to enable further treatments to be prescribed if necessary.

July 1961.

APPENDIX TO PART I - MILACRE SURVEYS FOR YOUNG REGENERATION

1. Example of the Booking Details

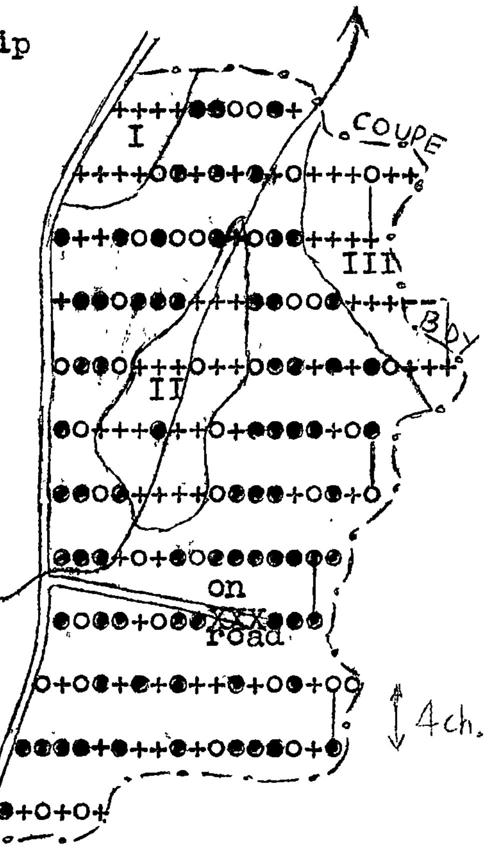
Col.1	Col.2	Col.3	Col.4	Col.5	Col.6	
11	B/D✓	✓			1½ch.	Dist. part stocked
10	B	✓				Note seed tree.
9	B	✓6"				6" seedling
8	U/B		✓			Unburnt/Burnt
7	U					Map burn boundary
6	U			creek		in field.
5	D/U			unburnt		
4	B/D	✓				Burnt part stkd.
3	D/B		✓			4-milacre stocked.
2	B	✓ 8"				8" seedl. on burn
1	D	✓ 2"				2" " on dist.
0	ROAD					

Strip No. 6. T.O.P. 5½ch. N of Spur Rd Bng 45°

Lords L.33 14/10/60 O.F. No.453 Pacing ABM.

Notes on location, date, compass no., pacing or chain, assessor(s), strip T.O.P., number and bearing.

2. Example of Survey Layout and Mapping



Strip	Milacre Score
12	3 out of 10
11	3 " " 18
10	6 " " 17
9	8 " " 18
8	6 " " 21
7	7 " " 17
6	7 " " 17
5	11 " " 15
4	8 " " 11
3	5 " " 17
2	10 " " 17
1	1 " " 6
TOTAL	75 " " 183

Understocked Areas I 0/8 = 0% (No seed trees)

II 1/20 = 5% (Mostly unburnt)

III 0/15 = 0% (Very dark, poor burn)

TOTAL 1/43 = 2½% Area = 43x0.4 = 17acs.

Stocked Areas TOTAL 74/140=53% Area =140x0.4 = 56acs.

Whole Coupe 75/183 = 41% milacre stocking. Approx 73ac.

STANDING INSTRUCTIONS FOR REGENERATION SURVEYS.

Part II. Stock Mapping for Older Regeneration. (4 yrs. and older.)

A. INTRODUCTION - The application of this type of survey, the best times to survey.

B. PREPARATORY OFFICE WORK - Making map sections, planning the survey.

C. FIELD WORK - Strip layout and booking procedure.

D. OFFICE WORK - Mapping rules and results.

E. MODIFICATIONS FOR CERTAIN CONDITIONS.

A. INTRODUCTION.

Stock mapping is designed to assess regeneration that has overcome early weed competition and which can be easily seen up to one chain away from the strip line. It is especially suited to fast growing eucalypts after about age four by which time they are usually 6' to 20' tall and above the fern layer which is generally less than 4' tall. Where other species such as silver wattle or musk coppice grow almost as fast as the eucalypts the system is modified slightly. Stock mapping is probably most efficient from about age 3½ to perhaps age 10. It is also useful where regeneration and advanced growth both contribute to the stocking. The sampling intensity is 40% but the count relatively inaccurate, compared with a very accurate count but of only ¼% intensity for milacre surveys.

B. PREPARATORY OFFICE WORK.

Sections of a 10 ch. map of a size that will comfortably fit on a booking board, are cut out and pasted on to cardboard. Parallel strips at 5 chain intervals are marked on the map in Indian ink. In addition, each strip is divided into sections one tenth of an inch long by short lines about 2/10" each side of the strips. This produces pairs of spaces about 1/10 x 2/10 inches in size along each strip. This rainproof grid is now ready for the field.

Only areas which are known to be capable of producing regeneration should be assessed e.g. areas with standing green remnant rain forest understorey are unlikely to regenerate properly without some major treatment. Similarly areas known to be regenerated by some other survey should not be assessed unless for comparative purposes. (e.g. area milacre surveyed previously etc.)

C. FIELD WORK.

The prepared map section takes the place of a field book. Also required are several very sharp pencils, a compass, a one chain band and two assessors.

The strips are located in the field and mapping started. The Chainman moves forward one chain along the strip counting all trees visible within one chain of one side of the strip. At the end of the chain he stops while the booker catches up counting all trees, on the other side of the strip. The booker then enters his score and the Chainman's score into the appropriate spaces on the map sheet. Counts should only be made up to 25 for each plot, after that the total should be estimated.

If either 1/10 ac. plot is not likely to become fully stocked with eucalypts the most important member of the other vegetation should also be noted in code form with the code and key recorded and kept constant for the survey, e.g. "P" for Pomaderris (Pear or Dogwood).

The estimate of one chain from the line should be checked at the start and end of the strip. No assessment should be made between strips on the tie-ins but all boundaries should be sketched-in.

The boundary between various obvious degrees of stocking, between species, sites or other vegetation should be sketched in from one strip to the next, wherever possible in the field.

D. OFFICE WORK.

After each day in the field the pencil plot score and code letters should be inked-in with waterproof ink. This is especially important if the map section is to be taken out into the field again.

At the end of the field work on an area a single map is prepared. Boundaries should be drawn as follows:-

1. All plots with five seedlings or less should be in the "Understocked" class except for the occasional isolated one in other classes.

2. All plots with from 6 to 15 seedlings should be in the "scattered" class, with the same exception.

3. All plots with 16 to 25 seedlings should be in the "enough" class, with the same exception.

4. All plots with 26 to 75 seedlings, should be in the "dense" class with the same exception.

5. All plots with more than 75 seedlings, should be classified as "Very dense".

This method of mapping will stratify the area into five classes. The average number of seedlings per plot should then be calculated for each class, and multiplied by 10 to give trees/acre.

A fair copy map showing only the strip lines and the boundaries and the number of trees per acre per class should be made. The boundaries produced by this map should be checked in the field if possible, especially the one between "understocked" and "scattered". The vegetation on the "understocked" and "scattered" classes should be marked in colours corresponding to the code used.

This "stock mapping" survey does not give an accurate total count of seedlings. It does give a reasonable estimate of the established seedlings. It also gives a useful map of the location of the various intensities of stocking, of species, and of the vegetations that have to be dealt with when restocking the "understocked" area. It is likely that the "scattered" class, although obviously not fully stocked will have sufficient trees which are generally well enough distributed to make filling by planting uneconomic.

Treatment such as planting, dozing, re-burning should be recommended where necessary at the time of the survey.

E. MODIFICATIONS FOR CERTAIN CONDITIONS.

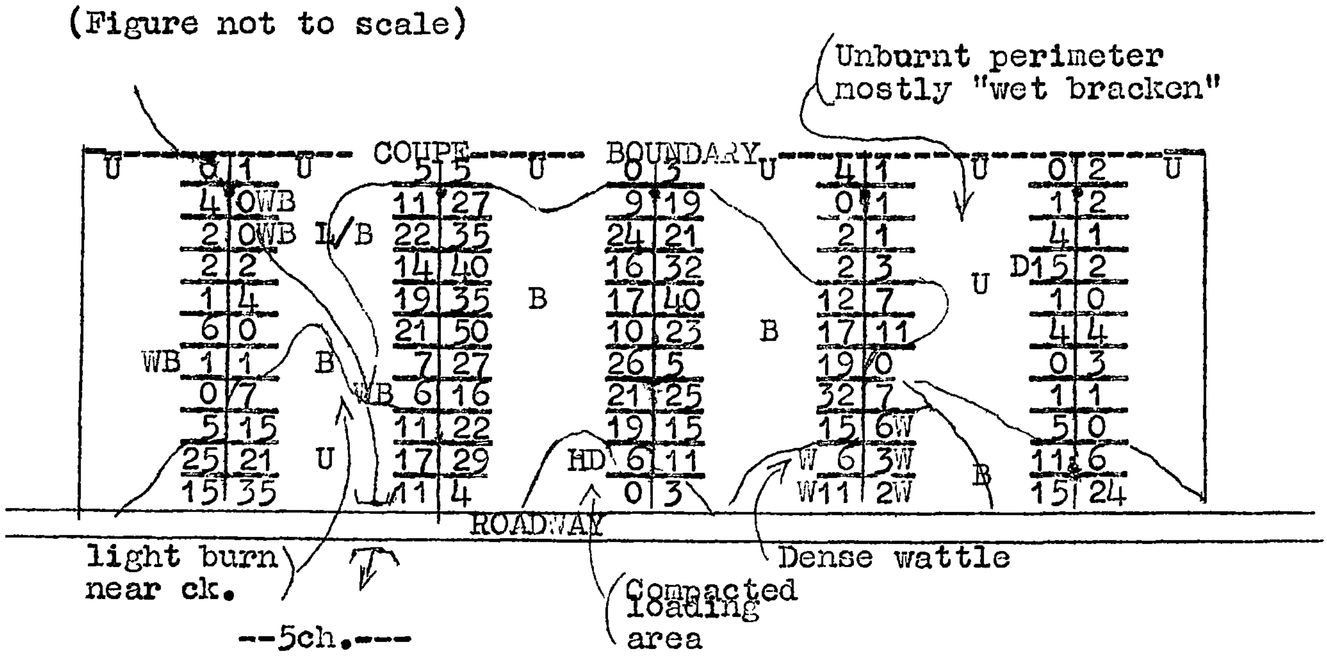
1. In very dense stands the distance from the chain can be reduced to $\frac{1}{2}$ch. or even 10lks. for counting purposes, but the figure entered on the map section should be that equivalent to a 1/10th. acre plot. The same applies where the competing vegetation is tall e.g. Silver Wattle.

2. Where advance growth also occurs it is desirable, if possible, to enter seedling and advance growth scores separately for each plot. The distribution of the denser patches of advance growth may be of great value in stand management.
   e.g. 6/15 equals six advance growth, 15 seedlings.
   0/6 " 0 " " 6 "
   21/0 " 21 " " 0 "

July 1961.

APPENDIX TO PART II - STOCK MAPPING OF OLDER REGENERATION

(Figure not to scale)



KEY B = Burnt
D = Disturbed
HD = Heavily Disturbed.
L/B = Lightly Burnt
U = Unburnt.

W = Wattle (Acacia dealbata)
WB = "Wet bracken" (Histiopteris, Hypolepis)

In this example the stocking classes "scattered" and "dense" cover so little area that they have been lumped with "enough". The wattle patch may require special treatment and has been mapped out separately

Stocked Area	1047 trees on 56 plots	=	187 trees/acre.
Wattle Area	28 " " 5 "	=	56 " "
Understocked	95 " " 49 "	=	19 " "
TOTAL	1170 trees on 110 plots	=	106 trees per acre

Areas of the various types can be estimated by dividing the number of plots in the type by 4 to give acerage:-

Stocked 56/4 = 14 acres

Wattle 5/4 = 1 acre

Understocked 49/4= 12½ acres

TOTAL 110/4= 27½ acres